The objective assessment of oral motor function during feeding: development and validation of the Schedule for Oral Motor Assessment (SOMA)

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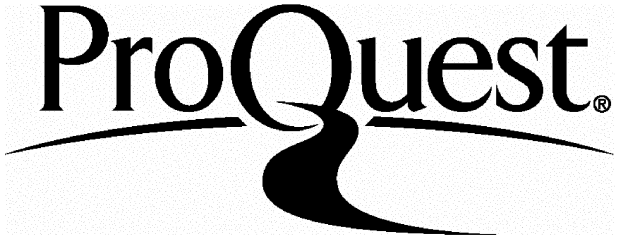

This thesis is dedicated to three important people.

- First to my partner Paul whose patience and support has been unlimited.
- Second, my daughter Nuala who will no longer have to preface utterances with 'Mum, when you finish your Ph.d.'.
- Third, to my father who did not live to see it completed but whose pride in my accomplishments was always present.

I would like to thank my supervisors, Professor David Skuse and Dr Helen MacConachie for their support and guidance.

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Abstract

No satisfactory method with established reliability and validity exists for evaluating oral motor functioning and identifying the extent of any dysfunction in infants and young children. Furthermore, the nature and extent of oral motor difficulties in children with cerebral palsy is unknown.

The objectives of the thesis are twofold: first, to develop an instrument capable of identifying children with clinically significant oral motor deficits and capable of discriminating them from children with normal oral motor function; second, to ascertain the reliability and validity of the instrument.

The Schedule for Oral Motor Assessment (SOMA) was developed to record oral motor skills objectively in infants with ages between 12 and 24 months. The procedure is rated largely from a videorecording of a structured feeding session. A series of foodstuffs of varying textures, including liquids, is presented to the child in a standardised manner. Oral motor skills are evaluated in terms of discrete oral motor movements.

One hundred and twenty-seven children have been studied with the instrument, including normal healthy infants and samples of children with non-organic failure to thrive, and cerebral palsy. Excellent inter-rater and test-retest reliability was established. Discriminant validity was investigated by means of a novel 'seeded cluster analysis' procedure. A further validation study on

an independent sample of children with cerebral palsy was undertaken.

Discriminant validity was satisfactorily established by the analysis and an abbreviated version of the SOMA, suitable for screening purposes, was developed. The screening version has been shown to have positive predictive values greater than 90% and sensitivity greater than 85% for the detection of children with clinically significant oral motor dysfunction.

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Chapter 1. Introduction

The human feeding cycle is dependent on an integrated sequence of events requiring the coordination of over 20 different muscles for the movement of saliva or ingested foods from the mouth to the stomach (Dodds 1989, Palmer 1989). Four distinct stages have been identified; the preparatory or anticipatory phase (Leopold and Kagel 1983), which involves food getting and anticipatory reactions; the oral stage (Leopold and Kagel 1983, Logemann 1983), involving bolus management and transfer, sucking, munching and mastication; the pharyngeal phase (Logemann 1983), during which swallowing occurs; and finally, the oesophageal phase which begins with the opening of the oesophageal sphincter (Miller 1982).

Successful oral feeding in young children is dependent on the subtle interplay between the structure and function of the oral cavity and other aspects of infant development such as sensorimotor function, neurological maturation, cognition, emotion and human interaction. The oral and pharyngeal skills that enable the infant to feed are part of a complex process which may be interrupted at any one or more points and result in feeding difficulties; such problems may be congenital or acquired and anatomical or functional in nature (Kenny et al 1989). Feeding infants and young children, particularly the consideration of how to achieve an adequate oral intake, has long been a neglected area (Bax 1989) of child development. This thesis is concerned primarily with evaluation of the oral stage of feeding and the difficulties that

may arise.

Feeding difficulties can be symptomatic of a variety of paediatric conditions. For many years clinicians have recognised that oral motor dysfunction occurs relatively frequently in association with conditions such as cerebral palsy. However, until recently, the topic received minimal attention in the literature (Bax 1989); many of the major texts dealing with the nature of cerebral palsy contain no mention of feeding difficulties.

The consequences of oral and pharyngeal dysfunction during infancy and early childhood range according to the severity of the problem. Whilst subtle defects may go undetected and cause minimal impairment and disruption, the most severe disorders can result in death due to aspiration pneumonia (Carter and Jancar 1983). For many years the growth failure associated with conditions such as cerebral palsy has been attributed primarily to the child's neurological condition. However, recent evidence has confirmed that oral motor difficulties may substantially affect the child's nutritional intake and consequently be one of the major causes of growth failure (Stallings et al 1993).

The malnutrition observed in children with severe oral and pharyngeal deficits can have long lasting effects on the child's health and well being. For example, factors such as an increased risk from intercurrent infections, decreased respiratory muscle strength, poor peripheral circulation, and

reduced attention span are thought to affect the child's ability to learn. In addition, decreased motivation and irritability are also frequently mentioned (Stallings et al 1993 and Stevenson and Allaire 1991). As well as influencing the health and well being of the child, feeding disorders may also affect relationships within the family. The burden of caring for a physically disabled child has long been recognised as a source of stress within the family (Sloper and Turner 1993, Reilly and Skuse 1992 and Stevenson and Allaire 1991).

As will be illustrated in chapter 2 (Literature Review) of this thesis there is a paucity of information about the development of oral motor skills. To date no longitudinal study has been undertaken in order to describe the development of oral motor skills in normal children. Yet in recent years there has been increasing recognition of how widespread the problem is in infancy and the significance of oral motor dysfunction for both the child and caretakers (Skuse et al 1992, Mathisen et al 1989, Reilly and Skuse 1992, Sonies et al 1990, Stevenson and Allaire 1991). However, there is considerable variability in the type of oral motor assessments undertaken and no assessment tool which has been standardised on normally developing children and has established reliability and validity, is available to evaluate oral motor function in paediatric departments in the UK.

The most common procedure used by clinicians is the bedside or clinic evaluation which usually takes the form of a 'feeding checklist'. In children with pharyngeal dysfunction the bedside evaluation may be accompanied by a

modified barium swallow if warranted. The development of an assessment tool capable of identifying children with oral motor deficits and discriminating them from children without oral motor dysfunction would be of value both clinically and for research purposes.

This thesis aims to develop an instrument, with established reliability and validity, which will enable clinicians and researchers to rapidly identify children with impaired oral motor skills. In Chapter 3 the hypotheses and aims of this study are proposed. The development of an instrument capable of distinguishing children with oral motor dysfunction from those with normal skills would have a number of benefits. For the first time a standardised description of both normal and abnormal oral motor behaviours could be made and children at risk could be provided with appropriate, 'early', intervention. In addition it would enable researchers to collect data on the prevalence of oral motor dysfunction in particular paediatric conditions. Having identified the extent of the problem, the service needs and resources required to effectively manage such difficulties could then be established. Finally, the identification of need and provision of appropriate services might prevent some of the severe consequences of oral and pharyngeal dysphagia, such as malnutrition from occurring.

Two studies were undertaken in this thesis. In Chapter 4 a description of the methodology and results of the first study, The Development Study, will be given. In chapter 5, the methodology and results from the Validation Study

will be described. In Chapter 6, the results obtained will be discussed and interpreted and conclusions drawn about the significance of the study and future research needs.

Chapter 2 Literature review

Part 1

The development of oral and pharyngeal function during infancy and early childhood

The use of terminology

Describing the normal process of food ingestion

There is considerable variation in the terminology used to describe both the normal process of food ingestion and the dysfunction that may arise. The client population in question affects the terminology used. For example, different terms are used to describe the process of eating and drinking in children than those used to describe the process in adults. During childhood, the terminology used relates largely to the child's developmental level and varies if the child is dependent on an adult for its nutritional needs or able to feed independently. Much confusion can and does occur both amongst professionals and between professionals and parents.

Table 1 summarises the terminology used most commonly in clinical practice in the field of paediatrics. The general terms shown are unsatisfactory in that they do not give any detail regarding which aspect of the complex process of food ingestion is referred to. Whilst some of the terms on the right are synonymous (swallowing and deglutition) others are not (munching and chewing). Clinicians and parents may use any of these terms to describe any aspect or stage in the feeding process. A framework for classifying and

describing the process of normal feeding is necessary.

Table 1. Terminology used to describe the normal process of food ingestion in children.

General terminology	Specific terminology
■ Feeding	■ Suckling ■ Sucking - nutritive - non-nutritive
■ Eating	■ Munching ■ Chewing ■ Mastication
■ Drinking	■ Swallowing ■ Deglutition

For the purposes of this thesis, the process of feeding in young children will be described in 4 stages:

- Anticipation/Preparation
- Oral
- Pharyngeal
- Oesophageal

It is not always possible to differentiate precisely between each stage. Although the distinctions are somewhat artificial, they are advantageous as they allow clinicians and researchers to accurately describe the process and more importantly to analyse the relationship of one stage to another. This thesis will be concerned primarily with the oral stage.

Describing abnormality

A variety of terms are used to describe any disruption to the normal process of ingesting food. It is equally important to be precise in the use of such terminology. In the literature the following terms are commonly used:

- Dysfunction
- Disorder
- Difficulty
- Deviant
- Dysphagia

Each of these terms may be combined with any one of the descriptors in Table 1 in an attempt to describe the child's difficulty. The manner in which it is described may indicate very little about the aetiology or exact nature of the problem. For example, a child described as having a 'feeding problem' or 'difficulties in feeding' could be seen by a variety of different health professionals all of whom have different expertise. The aetiology could be functional or organic or may have arisen as a combination of both factors. If, for example, the aetiology is organic, the description used may tell us very little about the actual difficulties the child is experiencing; are they at the anticipatory, oral, pharyngeal or oesophageal level or a combination of one or more of these?

The term dysphagia will be used to describe any difficulties which occur in the four stages of feeding. The term oral motor dysfunction will be used to describe the specific oral stage difficulties that are the focus of this thesis.

Figure 1 summarises the terminology used in this thesis to describe and classify abnormalities of the feeding process in young children.

Figure 1: Classification system used to describe abnormalities of the ingestion of food.

Definition: **"The term dysphagia is used to describe swallowing disorders characterised by difficulty in oral preparation for the swallow or in moving the bolus from the mouth to the stomach. Subsumed in this definition are problems positioning food in the mouth and in oral movements including suckling, sucking and mastication" (Edleman et al 1991).**

Anticipatory/Preparatory

Oral

Oral motor dysfunction: any difficulty in

- **suckling**
- **sucking**
- **chewing**
- **munching**
- **oral stage of swallowing**

Pharyngeal

Oesophageal

Structure and function of the oral cavity in infancy and early childhood

The development of oral-motor skills in infancy is primarily dependent on two main factors, the structure and function of the oropharynx. The pharynx, which is comprised of three main cavities, the oropharynx, nasopharynx and hypopharynx, is implicit to normal feeding. The pharynx is concerned with three main aspects of motor function: stabilisation and maintenance of structural position and form, alimentation and respiration (Stevenson and Allaire 1992). The pharynx is a common anatomic pathway for both respiration and digestion and requires complex and precise coordination from the neonate and young infant.

The structure and function of the oral cavity changes rapidly during infancy. The anatomic structures undergo growth which changes their physical relationship to one another and subsequently alters function. There are distinct structural differences between the oral and pharyngeal cavity of the young infant and the newborn which are beautifully illustrated and described in the work of James Bosma (1985, 1986, 1988). The newborn's lower jaw is smaller and retracted; oral space is limited because the tongue almost fills the entire oral cavity. The tongue appears enlarged as it touches both the floor and roof of the oral cavity as well as the cheeks and gum margins. The epiglottis and soft palate are closely approximated and the larynx is higher; together they create a protective mechanism which prevents the larynx from

penetration. The Eustachian tube lies in a horizontal position in young infants and becomes more vertically aligned in older children and adults. The sucking pads, fatty tissue deposits encased in the muscles of the infants cheeks, provide the infant with "firmness" or stability for sucking. Tongue movement in the newborn is restricted because of the limited oral space available and the immaturity of the central nervous system. A combination of factors enable the newborn to extract milk from the teat or nipple by compression and suction; these include, the stability of the mandible (provided by the sucking pads), the limited size of the oral cavity and the large tongue (in proportion to the size of the oral cavity).

Many anatomical and physiological changes, beginning at approximately 4-6 months, take place during the first year of infancy. Intraoral space slowly increases as a result of the lower jaw growing downwards and forwards, the sucking pads are absorbed and the oral cavity elongates vertically. The tongue has more space in which to move and continuous oral activity is seen; as well as extension and retraction, elevation and depression and cupping movements of the tongue emerge. Such movements enable the baby to form a bolus with either liquid or more solid foods. Greater control occurs in the form of voluntary jaw opening and closing. Both the cheeks and lips acquire greater mobility and the increased amount of oral play is thought to be an important factor in the development of sensorimotor feedback. At the same time the hyoid and larynx grow downwards creating increased separation between the epiglottis and the larynx which ultimately requires greater

respiratory and lingual coordination in order to control the direction of the bolus.

Bosma (1992) proposed that the anatomical development and functional patterns of the oral cavity were interdependent and suggested that oral motor functioning could stimulate the growth and structural adaptation of the oral cavity. He attributed the changes in the size of the pharynx, larynx and oral cavity to the actions of continuous feeding.

Development of sucking, chewing and swallowing

Developmental stages

Bosma (1992) divides the development of feeding skills into 4 distinct stages:

1. Early infancy - birth to 12 months.
2. Transitional feeding - 12-60 months
3. School aged children
4. Mature feeding - pubertal children and adults

The discussion will focus on Bosma's first 2 stages, early infancy and transitional feeding, as these are most pertinent to the thesis.

Development in Utero

Suckling and swallowing, the beginnings of oral development, have been observed very early in fetal life. Swallowing can be seen as early as 11 weeks and oral gestures, thought to be the forerunner of suckling, at 18 weeks

(Hooker 1942, Golobeva et al 1959). Suckle feeding develops rapidly after 33-35 weeks gestation and graduates from nonspecific mouth movements to a non-nutritive suckle and progresses to nutritive suckling coordinated with swallowing (Gyboski 1975, Wolff 1968, Herbst 1989). The act of suckle-swallowing in the fetus is thought both to provide training for suckle swallow in the neonatal period and to contribute to the complex regulation of amniotic fluid volume; the daily volume of amniotic fluid swallowed shortly before birth matches that of the mother's milk ingested shortly after birth (Pritchard 1966).

The role of the oral reflexes

The newborn begins life equipped with a set of reflexes which are considered necessary for survival. Prechtl and Beintema (1964) describe in detail the examination process for elicitation of the oral reflexes in the newborn infant and Sheppard and Mysak (1984) reviewed and summarised the published literature on infantile oral reflexes with detailed descriptions of the reflex, stimulus type and response.

The oral reflexes associated essential for establishing feeding include:

- rooting,
- mouth opening,
- lip,
- suck,
- swallow,
- bite,

- lateral tongue and
- babkin reflexes.

Each reflex can be elicited by applying a stimulus and observing the infant's response (Sheppard and Mysak 1984, Prechtl and Beintema 1964). Ingram (1962) considered that each oral reflex,

"represented a phase of a continuum of reflexely provoked motor activity."

and therefore should not be examined individually. The oral reflexes enable the neonate to feed successfully and the protective reflexes such as the gag and cough reflexes ensure safe feeding. The rooting reflex is often described as a searching movement which enables the baby to find the nipple or teat. Prior to a breast feed, when the baby is alert and hungry, he/she can be seen to 'root' for milk; the reflex helps to guide the baby towards the breast without direction from the mother. Present at birth the reflex can still be elicited in approximately 80% of infants at 6 mths of age (Touwen 1976). Once the baby has found the breast the mandible is depressed (mouth opening reflex), the lips separate and orientate towards the stimulus enabling the baby to close the mouth (bite reflex) and to latch onto the nipple (lip reflex-lateral). The baby is then able to initiate the suckle-swallow sequence (suck and swallow reflexes).

The oral reflexes described are also dependent on other aspects of the child's physical development, for example, the rooting reflex depends on head movement including turning, slight elevation and flexion. The gag and cough

reflex serve as protective mechanisms which help to prevent laryngeal penetration. Unlike the other oral reflexes which disappear during the first 12 months the protective reflexes are present throughout life although the sensitivity of the gag reflex is thought to diminish around 6-9 months when the solid food the baby is receiving is of a firmer consistency.

More recent work carried out by Sheppard and Mysak (1984) suggested that studying oral reflexes is useful. They found that the oral motor behaviours involved were very similar to early chewing patterns. They concluded that chewing appears to develop as a result of the functional interaction between reflexive and adaptive movements.

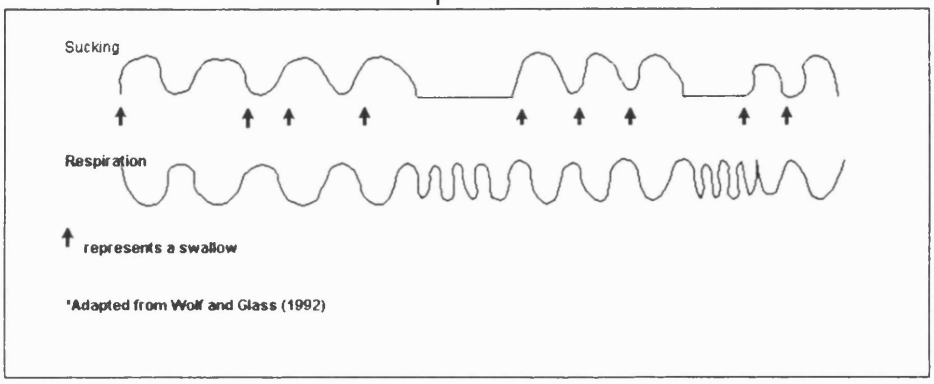
The elicitation of oral reflexes during infancy does appear to warrant some attention. First, they can provide useful information about the infants capacity to feed if they are observed as a part of the feeding process. Second, the reflexes may provide the clinician with useful information about the emergence of oral motor behaviours such as chewing.

Development in infancy and the transitional period

For ease of discussion sucking and swallowing will be described separately, however, functionally, it is difficult to separate suckling/sucking from swallowing as they do not occur as distinct events but overlap in a precisely coordinated sequence. Mature sucking is organised into a series of sucking

bursts and pauses. During the sucking bursts, respirations are interspersed with sucking and swallowing as can be seen in figure 2.

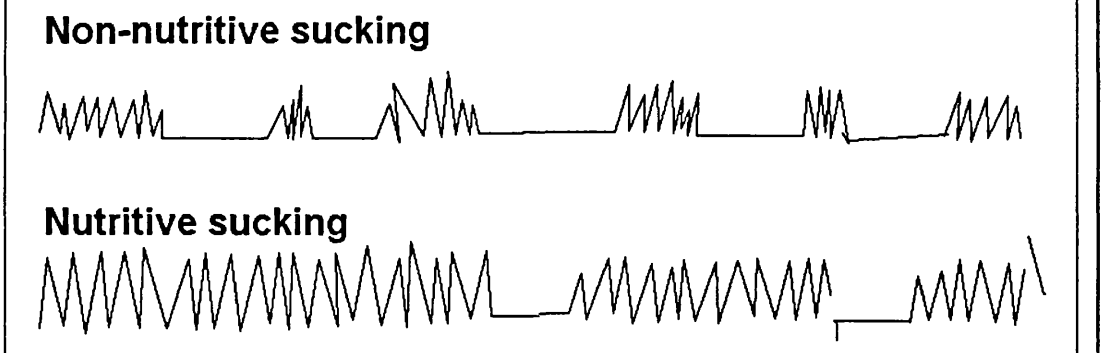
Figure 2. Normal coordination of sucking swallowing and respiration*



Development of sucking

Sucking may be nutritive or non-nutritive. Nutritive sucking refers to the process of obtaining nutrition or ingesting food whilst non-nutritive sucking occurs in the absence of any flow of nutrients. Non-nutritive sucking may occur to satisfy the infants desire to suck or as a state regulatory mechanism (Wolf and Glass 1992)

Figure 3. Non-nutritive and nutritive sucking patterns



Adapted from Wolf and Glass (1992)

Sucking is the intake phase; it involves taking the liquid or food into the mouth 1992). The characteristics of these two types differ as can be seen in figure 3. Sucking is the intake phase; it involves taking the liquid or food into the mouth and moving it back in preparation for swallowing. Morris (1987) states that sucking needs to be easily initiated, rhythmical, strong, sustained and efficient.

Two types of sucking are usually described during the infant's early development; they are suckling and sucking. Suckling is the earliest pattern seen and is often described as a type of licking because of the distinctive extension-retraction movement of the tongue. The lips may not always be fully sealed around the nipple or teat and some fluid escape is seen. Sucking is the second pattern to develop and involves the use of the intrinsic muscles of the

tongue. It is sometimes referred to as pump sucking. During sucking the tongue, along with the hyoid bone, mandible and lower lip are moved in phases, downwards and forwards and then upwards and backwards to express milk from the nipple. Bosma (1990) demonstrated through the use of ultrasound that there was a 'peristaltic displacement' of the medial portion of the tongue which occurred in wave like patterns of contraction and relaxation. These actions result in a milking or compression of the liquid from the nipple or teat. The lateral portions of the tongue function as stabilisers which enclose or cup the nipple or bolus and milk is moved into the pharynx by peristaltic waves in preparation for swallowing; the swallow is triggered when the bolus reached the posterior pharyngeal wall (Bosma 1992). Not every sucking action is followed by a swallow; two or three sucking actions may precede one swallow.

In the newborn and very young infant the position of the epiglottis helps to prevent aspiration and direct or divert the liquid laterally around the laryngeal opening (Stevenson and Allaire 1992). Crelin (1973) described the upward movement of the epiglottis to guide the larynx upwards behind the soft palate where it remains allowing smooth respiration to take place during suckling-swallowing.

The suckle-swallow, respiratory pattern observed in young infants occurs in a stable, rhythmic pattern. (Vice et al 1990, Keonig et al 1990, Daniels et al 1990). Each infant has a unique suck-swallow pattern interspersed with

respiration, the sequence is smooth and rhythmic and rapidly becomes established during the first weeks of life .

Development of swallowing

Humans are thought to swallow approximately 2,400 times per day in a 24hr period and as much as 300 per hour during eating or drinking (Sakuda et al 1975). The act of swallowing serves two functions: to propel a bolus of food or liquid from the oral cavity into the oesophagus and to prevent aspiration of the bolus into the larynx. Swallowing is an extremely complex motor sequence which has stimulated much research of both animal and human deglutition systems. It is a triggered all or none sequence of movements; that is, once initiated it cannot be interrupted (Sessle 1981). Swallowing involves the coordination of a large number of muscles in the mouth, pharynx, larynx and oesophagus and is usually divided into 3 phases, oral, pharyngeal and oesophageal. The oral phase involves bolus management and transfer, food or liquid is prepared, whether by sucking, munching or chewing, and propelled backwards in preparation for the swallow. During the pharyngeal phase the swallow reflex is triggered and in the oesophageal phase, food passes into the oesophagus. The anatomic and physiologic components of the swallow have been extensively described by numerous authors (Doty and Bosma 1956, Sessle 1981, Bosma 1957, 1992).

In young infants the swallow nearly always occurs with a suckle, however at

about 6-8 months Morris and Klein (1987) suggest that a new type of swallow develops. The more mature swallow results in the infant being able to trigger a swallow independently, that is without it being preceded by a suck or suckle action. The swallow undergoes further development as the infant learns to drink from a cup which requires greater oral and pharyngeal control of a larger and faster flowing bolus. However, there has been no major study of the changes that occur in the swallow pattern either in relation to the changing size or texture of the bolus in children.

Development of chewing

Chewing is a complex, coordinated action involving the entire musculature of the oral cavity. The major function of chewing is to lubricate and reduce each mouthful of food to a particular size convenient for swallowing. Chewing cycles are variable with no two cycles ever being identical; they are dependent on continuous sensory feedback from the oral structures (Ahlgren 1966). The musculature and structures required for chewing are present from birth, apart from the teeth which erupt at different stages during the first 18 months. Chewing is commonly thought to emerge between 5-8 months of age (Morris and Klein 1987).

Many researchers believe that there is a considerable and variable postnatal learning period before chewing emerges (Sessle 1981, Illingworth and Lister 1964). The transitional stage of feeding is however, the least well understood; little study has been made of the physiologic process underlying the transition

from liquid to more solid feeds. Sessle (1981) highlights the fact that we do not know whether mastication utilises some of the pathways and mechanisms already in use for suckling or whether the nervous system develops new mechanisms which may for example be triggered by tooth eruption. Any study of the emergence of such skills is complicated by many factors which may influence how and when the oral motor skills required for chewing or munching foods are acquired. For example, the age at which texture is introduced may vary according to cultural attitudes and the recommendations and trends for infant feeding.

The emerging oral motor skills necessary for chewing have been studied by most researchers as the introduction of solids takes place (Alexander 1987, Lewis 1982, Morris 1987). Most studies are descriptive and have involved small samples of children; specific stages which coincide directly with the offering of increasingly textured foods have been identified as oral motor milestones and the children observed at these time points.

Sheppard and Mysak's (1984) study of young infants is the only systematic observation of solid bolus feeding which was not been linked to the milestones described above. They studied just 2 infants at monthly intervals from 1 week until 35 weeks. From the first session, the infants responded to a chewable bolus of food (cube of banana) with task orientated movements such as mandibular elevation and depression, lateral tongue movements and bolus transport from the lateral to medial position. Lateral and protrusive

movements of the mandible and mandibular depression and elevation at speed (approximately 1 cycle per second) were among the last characteristics of mature mastication to emerge at 26-31 weeks of age. The infants studied by Sheppard and Mysak were not receiving a diet containing chewable solids. Some components of chewing, such as mandibular elevation and depression and lateral tongue movements were considered similar to infant oral reflexes. They concluded that the emergence of the oral motor movements necessary for chewing could be observed well before the onset of functional chewing when infant oral reflexes were active (Sheppard and Mysak 1984).

The introduction of solid foods or weaning in Western countries usually coincides with spoon feeding, although occasionally infants may have been exposed to bottle feeds thickened with cereals which resemble a thin puréed texture. Spoon feeding requires the infant to learn gradually a totally new pattern of food intake and to deal with a different texture. Not surprisingly the majority of infants initially persist with a sucking pattern to try to remove the food from the spoon; they are unable to stabilise the jaw or to grade opening and closing movements to accommodate the spoon. The lips remain inactive as they are used to moving in an integrated sequence with the mandible and tongue; the separation of movement described by Morris (1987) slowly takes place and the lower lip begins to seal around the spoon and the upper lip assists in removing food from the spoon at about 7 months (Morris 1987). The introduction of semi-solids or solid foods usually coincides with the eruption of the teeth and is often accompanied by some coughing and choking as the

child learns to deal with a more solid bolus of food.

Morris describes 4 sequential stages which occur in the development of mandibular movements for chewing. They are:

- the stereotyped, vertical pattern
- the non-stereotyped, vertical pattern
- the diagonal, rotary pattern and
- the circular, rotary pattern.

Early chewing movements, often described as munching, are seen as the precursors of more mature chewing actions. Munching consists of vertical mandibular movements combined with elevation and depression of the tongue Morris (1987). Occasionally, gross tilting movements of the tongue may also be observed. Gradually the tongue and jaw orientate towards the stimulus if it is placed onto the molar gum margins; this is thought to be the beginning of the diagonal rotary jaw movements seen in the more mature chewing pattern.

The variety and extent of jaw, tongue and lip movements seen during chewing is dependent on the size and texture of the bolus. In mature chewing the tongue moves laterally from the central position to place food onto the molars and can transfer food back to the medial portion of the tongue in preparation for swallowing. The tongue also transfers food from one molar region to another in a graceful curling movement; the tongue tip helps to precisely place the food. The mandible moves initially in a lateral direction from side to side

depending on where the food is positioned. Gradually rotary-circular movements develop which assist the tongue with placement and enable the child to manage a large bolus of food. A grinding action is sometimes observed to masticate tougher textures such as meat.

Gisel and her colleagues (Gisel 1991, Stolovitz and Gisel 1991, Gisel 1988a, Gisel 1988b, Schwartz et al 1984) have contributed a great deal to our knowledge of chewing patterns during early childhood. They found that the initiation of chewing becomes more efficient as children are exposed to more solid textures, the tongue becomes more mobile and independent of the jaw which is in agreement with Morris's (1987) description of separation of movement. The ability to manage different food textures (eg: purée verses solid textures) was found to mature at different rates and optimal efficiency is not reached until well after 2 years of age. However, many of Gisel's studies have been concerned with the duration of the feeding cycle rather than evaluating the individual oral motor movements. Whilst this work enables us to compare the duration of the feeding cycles according to the textural property of the foodstuffs, in both normal children and children with CP, it does not describe the discrete oral motor movements that are involved.

Neurological Control of sucking, swallowing, chewing and respiration

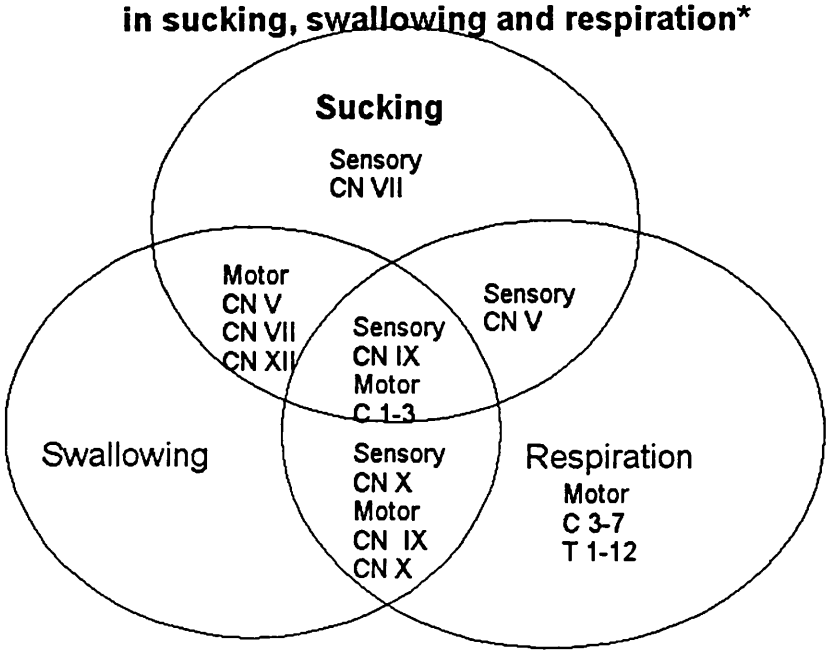
Sucking, swallowing and respiration

There is considerable overlap in the neurological control of sucking,

swallowing and breathing. Both the sensory and motor components should be considered, although the former receives scant attention in the literature. This probably arises from the fact that the motor aspects can be more easily observed whereas it is not possible to quantify sensation and the child's response to stimulation cannot be objectively described. Figure 4, adapted from Wolf and Glass (1992), illustrates the specific motor and sensory functions of the cranial nerves (V, VII, IX, X and XII) and branches of the upper cervical nerve roots which innervate the oral, nasal, pharyngeal, laryngeal and respiratory structures.

A more detailed discussion of the sensory and motor functions of the cranial and cervical nerves involved in sucking, swallowing and respiration and their representation in the brainstem can be found in Wolf and Glass (1992). They provide a summary and illustrate the complexity of the organisation of brain stem control of sucking, swallowing and respiration.

Figure 4. The overlapping function of the cranial nerves involved in sucking, swallowing and respiration*



* adapted from Wolf and Glass (1992)

The swallowing neurons in the nucleus tractus solitarius (NTS) and the adjacent reticular formation play a major role in the initiation and integration of swallowing.

The neurological control of chewing

The neurophysiology of chewing is not well understood; a number of different theories have been generated. One of the earliest theories was that proposed by Sherrington in 1917 called the 'peripheral control' or 'reflex chain theory'. This combined with other hypotheses generated by Rioch in 1934 were generally accepted until the seventies. The masticatory cycle was seen as an oscillatory reflex movement, cortically induced and maintained by peripheral

feedback from the proprioceptors of the masticatory muscles innervated by the trigeminal nerve (V).

In the seventies, new theories emerged which suggested that the control system for mastication was based below the mesencephalon, since decerebrate animals (above the pons) were capable of chewing (Dellow and Lund 1971). The chewing centre is located in the reticular formation, adjacent to the rostral end of the mesencephalic nucleus of the trigeminal nerve. The masticatory centre contains a pool of interneurons, which initiate and maintain an alternating rhythmic activity to open and close the mandible and extend and retract the tongue. Mastication is an internally programmed cyclic activity; the neural circuits involved utilise the V, VII, IX and XII cranial nerves in a highly complex, smooth coordination of the various oral motor structures.

Sensory feedback is a crucial component in chewing and is provided by the intraoral stimulation of food. The oral mucosa, gums, periodontium, palate, tempero-mandibular joint receptors, proprioceptors in the mandible, receptors in the tongue, taste buds and mechano-receptors in the lips and the skin of the face provide feedback. The activity of chewing is subject to considerable modification. The continuously changing consistency of the food, bolus size, shape and placement within the oral cavity ensures that each chewing cycle is uniquely different.

Table 2. Sensory and motor functions of cranial nerves involved in mastication

Cranial nerve	Motor efferent function	Brain stem representation
Trigeminal CN V	■ Muscles of mastication ■ Lower jaw	■ Trigeminal motor nucleus
Facial CN VI	■ Muscles of the face buccinator stylohyoid posterior belly diagastric	■ Facial nucleus
Glosspharyngeal CN IX	■ Pharynx	■ Nucleus ambiguus
Hypoglossal CN XII	■ Tongue	■ Hypoglossal nucleus
Cervical nerves 1-3	■ Paramedian muscles between mandible, hyoid and shoulder girdle	■ NA: spinal column
	Sensory afferent function	Brain stem representation
Trigeminal CN V	■ Scalp, face, teeth, tongue, mebranes of mouth, palate, nose, nasal sinuses	■ Trigeminal sensory nucleus
Facial CN VII	■ Taste to anterior 2/3 of tongue ■ Middle ear	■ Geniculate ganglion to the NTS
Glosspharyngeal CN IX	■ Pharynx ■ Posterior 1/3 of tongue (taste) ■ Carotid sinus	■ Superior and inferior ganglion to NTS
Hypoglossal CN XII	■ None	
Cervical nerves 1-3	■ dermotones of head, neck and shoulder	■ NA: spinal column origin

Since the seventies, mastication has no longer been considered a purely reflexive activity confined within a fixed pattern or motor response to an appropriate stimulus.

Mathews (1975) likened the masticatory cycle to flying a plane:

> " The masticatory control can be compared to an automatic pilot, which will steer the plane on its own but which has manual over-ride facilities by which the pilot can take control should he wish to do so."

The relationship between oral and pharyngeal development and gross motor development

It is important to place the emergence of oral motor skills into a developmental context; the oropharynx should not be studied in isolation but considered within the context of the whole body. Gross motor functioning affects to a great extent the function of the oropharynx. Morris (1987) mentions 4 aspects of gross motor control which she considers influence development of feeding.

They are:

- Stability and Mobility
- Separation of movement
- Straight planes of movement to rotation and
- Midline development

Without postural stability and a stable base the infant will be unable to develop controlled, functional movement. Oral stability is dependent on the development of the neck and shoulder girdle which are in turn dependent upon trunk and pelvic stability. A child with gross physical impairment and

poor trunk stability will be unlikely to be able to stabilise the head and neck and as a result will almost certainly be unable to develop jaw stability.

Children's movement patterns progress from gross to fine motor development. This concept relates to both the sequence of development taking place for the total body and for oral motor skill acquisition. Early jaw movements initially appear gross and unrefined, for example, the baby or young infant is unable to grade jaw opening movements. However, with the development of total body and oral stability the infant's repertoire progresses rapidly to include finely graded jaw movements. For example the older infant is able to grade the exact degree of jaw opening required for different sized crackers. At the same time there is a gradual separation of movement. The young infant who tries to grasp an object will initially use a palmer grasp and his/her reach will involve the whole body; at times this may result in the infant lo sing balance. Gradually however, the infant learns to finely tune the movement so that they can pick up an object with a fine pincer grasp and isolate or separate the required movements from the rest of the body. In the same way, infants learning to cope with their first mouthfuls of solids will suck on the spoon and initially bite on the spoon to stabilise the lower jaw. Gradually however, the baby develops internal stabilisation.

Body position during feeding changes dramatically during the first 12 months of life. From birth until approximately 3 months, the majority of infants are fed in a supine or semi-reclined position during breast and bottle feeding. From 3

months onwards most infants sit in a well supported semi-sitting position although they may still be reclined at an angle. By seven months, most are seated upright with back support provided by an infant chair, although they may require the extra help of cushions, or inserts. By nine months most no longer require back support unless they tire and by 18 months the majority of children can sit unsupported at the family table or a small child's table and chair.

The position of the head and neck during feeding are of extreme importance. The patency of the airway can be affected by the degree of neck flexion or extension (Logemann 1983 and Wolf and Glass 1992). Bosma (1992) proposed that the maintenance of the pharyngeal airway is the antecedent of craniocervical posture and that the development of this posture begins with stabilisation around the pharyngeal airway in the infant. The airway continues to play a central role in postural mechanisms during the infants life.

Oral skill development in relation to foodstuffs

The role of texture in the development of oral skills

For the first few months of life the infant relies exclusively on liquids (milk) as the main source of nutrition and between 3 and 6 months is exposed to 'solid foods.' The use of the term 'solid foods' is somewhat misleading as initially most infants are fed foods of a puréed consistency which resemble thickened liquids. Perhaps the major difference is in fact the manner in which it is presented, on a spoon rather than in a bottle. This phase is often referred to

as transition feeding or weaning. The majority of infants negotiate this transition successfully although it can be problematic for some. Gradually thicker purées are introduced followed by foods containing lumps and ground or mashed table foods (8-12 months). By about 12-18 months most infants are regularly eating coarsely chopped table foods and easily chewed meats and finally by 18-24 months they are able to manage an adult diet of meat, raw fruit and vegetables.

The timing and introduction of the various types of solid foods are controlled by the parent. Guidelines for feeding infants are regularly published in the United Kingdom by the Department of Health (1989) and parents are often advised by health visitors. There is, however, a paucity of information about the individual and contextual factors that contribute to successful transition feeding and wide variation in the age at which infants are introduced to different textures. There is limited information detailing how infants manage the transitory stages and little or no information on how texture may facilitate or impede the development of oral motor skills.

Because many studies of oral motor functioning have been based on the premise that the development of oral skills parallels the types of food introduced it has been assumed that liquids and foods of a softer texture such as purée are easier to manage than more solid textures such as a biscuit. However, Gisel (1991) recently suggested that the maturity to eat a solid texture such as a biscuit was reached earlier (at 4 years) than that of a

purée (6 years) and a viscous texture (7 years). Maturity was reached when no further decreases in time were noted to eat the relevant texture. Gisel and Patrick (1988) concluded that a firmer food texture elicited a more mature eating pattern as it was easier to manipulate a solid food bolus. Gisel (1988, 1991, 1992) has consistently stated that solid foods are easier to manipulate because children revert to suckling on puréed textures when they should in her view be using a more mature chewing pattern.

This particular aspect of Gisel's work is confusing and contradictory; first, neither children nor adults use a 'mature chewing pattern' to manipulate a puréed texture; purées do not require mastication. Second, Gisel (1991) states that infants use the feeding method that requires the least effort; that is, if food can be ingested by suckling, the child will not munch. To suggest therefore, that a child's oral motor behaviours may be less mature or abnormal solely on the basis of the duration of the feeding cycle alone is insufficient. Whilst the duration of the feeding cycle is an important factor, maturation should include an evaluation of the discrete oral motor movements required for mature oral feeding. For example, control of the lips, tongue and mandible are of equal importance.

The influence of texture on the development of oral motor skills remains unknown with the results of the few available studies being inconclusive. Shepperd and Mysak (1984) suggest that infants may respond to a chewable bolus placed on the gums with task orientated movements as early as 1 week

of age. Other researchers have suggested that such movements do not emerge until much later (Morris 1987, Lewis 1982). For many years clinicians and researchers believed that the eruption of the teeth was an essential part of the successful transition to solid foods. This has, however, been shown to be incorrect as many infants can manage mashed and coarsely chopped foods prior to the eruption of the primary dentition (Bosma 1986). It is apparent that there are many misconceptions regarding oral motor ability during infancy and the assumption that the emergence of oral motor behaviours parallels the introduction of the food texture may in fact be incorrect and certainly warrants further investigation.

A critical or sensitive period

The notion of a period of heightened susceptibility can be found in psychological writings as early as the 1890's. However, the term a 'critical period' was not coined until much later when a number of researchers developed their theories on the basis of the large literature about critical periods in animal studies (for example, Bowlby 1953, Lorenz 1935, Denenberg and Bell 1960).

The idea of a critical period is based on the premise that during development infants pass through phases when they are sensitive to particular influences; during other stages of development, they may be less sensitive or insensitive to the same influences. The phase is usually a well delineated period of time when a specific stimulus must be applied in order to produce a particular

action; the sensitive period refers to the optimal time for the application of such a stimulus.

The critical period for a given development is closely related to the level of maturation of the central nervous system; Nash (1973) proposed that unless the CNS had reached a minimum state of maturation and had begun to function the critical event would be ineffectual. Bronson (1962 and 1965) said critical periods could be organised into 3 categories; first, the nature of the stimuli to which the infant was sensitive; second the nature of the behaviour patterns that were affected; and third, the developmental stage during which these stimuli had their maximum effect on later behaviour.

The concept of a critical or sensitive period for oral motor development was first proposed by Illingworth and Lister (1964). They defined the term 'critical period' as a well-delineated period of time during which a specific stimulus must be applied in order to produce a particular action. A 'sensitive period' was considered to be the optimal time for the application of a stimulus. They proposed that if children were not given solid foods to chew at the appropriate time or solid foods were withheld (eg: delayed weaning), troublesome feeding problems could develop. Illingworth and Lister (1964) cited a number of case studies to illustrate their ideas and suggested that a child was developmentally ready to chew at 6 mths.

The concept of a critical period although unproven remains widely accepted

by clinicians as providing an explanation for some of the paediatric feeding problems commonly encountered. Children who experience prolonged tube feeding are thought to be deprived of oral experience during 'critical periods' of infancy or exposed to adverse oral experiences; as a result many become resistant to oral feeding long after the need for enteral feeding has elapsed (Morris 1985).

Bosma (1992) felt there was a relationship between the structural development of the oral cavity and the degree of practice. A recent study by Bier et al (1993) showed that low birth weight infants who had undergone prolonged intubation had significantly poorer sucking abilities at term and 3 months than infants of low birth weight with short periods of intubation and full term infants who had not been intubated. A contributory factor was thought to be the structural changes that occurred as a result of intubation-related injury or side effects such as palatal groove (Molteni and Blumstead 1986). The impact of palatal groove formation on the sucking patterns of young infants remains unknown; however, one could hypothesise that such a change in the structure of the oral cavity of young infants could disturb the relationship of the oral structures and create additional oral motor control difficulties for the young infant. The authors concluded that prolonged intubation may be viewed as a marker for potential oral motor problems.

In summary, the concept of a critical stage or sensitive period for the introduction of feeding stages appears to be an important one. The few

studies concerned with the subject add weight to the view that oral experience is an important component in the development of oral skills and suggests that even in the very young infant there may be a critical age for the introduction of solid foods. However, our understanding of the mechanisms involved are at this stage rather limited.

The development of self feeding

Self feeding skills need to be learned as motor skills mature. The first stage in learning to self feed begins with mouthing activities from the age of 2-3 months. Such activities can have a calming effect on the infant and be self regulatory. From 3 months onwards, the child is able to bring objects to its mouth and begins to recognise the bottle and anticipate its approach with changes in activity and movement such as kicking the legs, wriggling or sucking movements (Sutter 1991). By four months infants are able to purposefully reach for objects and the frequency of mouthing increases, they may touch and pat the bottle and place their hands on it (Morris and Klein 1987). By five months many are able to hold their own bottle.

When the child is introduced to solids he/she may hold a rusk and gum foods (Sutter 1991). By nine months the infant is able to bring a biscuit to the mouth and eat it independently, but it is not until 12-14 months the infant is able to bring a loaded spoon to the mouth (Stevenson and Allaire 1991). The ability to self feed with a spoon is dependent on the development of hand function in particular wrist lateralisation and rotation which make it possible to carry food

to the mouth without spillage. As in all aspects of feeding development practice improves the performance and is an important component of self feeding development.

By 24 months of age the child may also be able to stab food with a fork, but it is not until 36-48 months that a child's ability to self feed with a fork or spoon fully matures (Morris and Klein 1987). The sequence of cup drinking develops in a similar fashion and is equally dependent on experience and motor maturity. At six months the infant can drink from a cup held by an adult and at 12 months can hold the cup and drink but will probably spill some liquid (Fomon et al 1979). At 24 months the child can usually hold a cup in one hand and drink and at 30-36 months can pour liquid into a cup. Obviously abilities in this area depend on practice and the type of utensil given to the infant. The use of trainer cups, that is cups with a spouted lid, are common in the UK and many children continue to drink from these well into childhood although they are more than capable of controlling the flow of liquid from an ordinary cup.

Very little is known about the emergence of straw drinking. Morris (1987) mentions the age of 2 years as the average age when children are able to drink from a straw. Again experience is of great importance. However, some children as young as 6 months can drink from a straw. The increased popularity of boxed drinks in the UK may result in some children learning to suck from a straw at an earlier age than was previously thought possible. However, they do so initially by squeezing the carton which forces juice up the

straw.

Conclusions

There is no doubt that the acquisition of the oral and pharyngeal skills necessary for adequate feeding is a complex process. Whilst physiological maturation is a very important factor in the child's ability to feed, learning also plays a major role. The contribution of both factors are not well understood. For many years the subject has been neglected. Infant feeding was covered extensively in numerous nonscientific publications concerned with the more general aspects of child care. As a result it did not seem a respectable one for researchers and clinicians to investigate (Bax 1989). Much of the literature is therefore descriptive and consists of small observational studies or anecdotal reports of small groups of children.

Part 2

Dysphagia in Infancy and Early Childhood

Types of dysphagia

Illingworth (1969) reviewed the literature on paediatric dysphagia between 1879 and 1968 and found that many textbooks did not include the word dysphagia or a suitable synonym in the index. He concluded that this may have been partly due to the fact that many affected children are referred to a variety of specialists, including paediatricians, otolaryngologists, maxillofacial surgeons, plastic surgeons and speech therapists. Although there has been an increasing amount of literature published on the subject, a perusal of many of the major paediatric textbooks recently published revealed that the situation is little changed since Illingworth's review. However, in recent years the publication of three new comprehensive texts on Dysphagia (Wolf and Glass 1992, Brodsky and Avardson 1992, Rosenthal et al 1995) and the publication of the journal Dysphagia in 1986 have contributed much to our understanding of many aspects of infant feeding.

Dysphagia can be congenital or acquired and anatomical or functional in nature. It can occur at any time during the life cycle; symptoms vary according to the cause. Table 3, adapted from Carrol and Reilly (1995), shows the causes, symptoms and consequences of dysphagia in one group of children, those with cerebral palsy (Reilly 1993, Carroll and Reilly 1995). Illustrated clearly in the table are the 4 stages involved in the ingestion of

food. Whilst the information in the table refers specifically to children with CP, it is also relevant to many other paediatric conditions. Children with CP almost certainly form the largest paediatric group known to have coexisting dysphagia.

Dysphagia of the oral stage, referred to in this thesis as oral motor dysfunction refers only to those difficulties originating in the oral area. However, it is somewhat artificial to separate completely the 4 stages of feeding, (preparatory, oral, pharyngeal and oesophageal) as they are closely interrelated and each is dependent on the precise coordination of the preceding and subsequent stage. Furthermore, a disorder of one phase can affect the function of other stages.

Kramer (1985) provides a detailed description of the special feeding problems that occur in children. In addition, Cohen (1990), Fisher et al (1981) and Painter (1981) provide detailed descriptions of the range and type of paediatric feeding disorders. They are commonly divided into distinct groups according to the aetiology of the presenting problem and include:

- prematurity
- upper airway obstruction
- acquired structural problems
- congenital defects of the larynx, trachea and oesophagus and
- neuromuscular disorders
- non-organic or behaviour problems.

Oral motor dysfunction may occur as a result of a combination of these factors, however it is not always attributable to a known aetiology. Some researchers and clinicians report that dysphagia sometimes occurs 'temporarily', which they ascribe to either immaturity or a transitory central nervous system aberration that spontaneously subsides (Cohen 1990). Oral motor dysfunction is also known to occur in association with some conditions, for example non-organic failure to thrive, where the aetiology for the disorder remains unclear (Mathisen et al 1989., Skuse et al 1992., Reilly et al 1993, Ramsey et al 1993). Occasionally oral motor dysfunction is said to occur as a result of behavioural or emotional problems (Koon 1983., DiScipio et al 1978). Recent studies have identified oral motor dysfunction in infants and young children with congenital growth disorders such as Turner syndrome (Mathisen et al 1992), and in children with renal failure (Sonies et al 1990).

Table 3. The causes, symptoms and consequences of feeding problems in children with cerebral palsy (Reilly 1993, Carroll and Reilly 1995)

Causes	Symptoms	Consequences
Oral motor dysfunction • difficulty sucking, chewing, munching and/or swallowing • poor bolus formation	• excessively long mealtimes • excessive food loss and drooling • spitting • dental pain/caries	• inadequate nutritional intake • specific nutrient deficiencies • prolonged mealtimes
Pharyngeal dysfunction • aspiration of food/liquids • slow pharyngeal transit time • reduced peristalsis • delayed/absent swallow reflex • reduced laryngeal closure • incomplete clearance of residue	• coughing • choking • gagging • noisy respiratory pattern • altered phonation • upper respiratory tract infections	• failure to thrive • dental caries • increased risk of infection • upper respiratory tract infections • urinary tract infections
Oesophageal dysfunction • gastroesophageal reflux • delayed gastric emptying • oesophagitis • aspiration of GOR	• regurgitation • vomiting • abdominal discomfort • coughing/choking	
Gross motor impairment • cannot seek out food • inability to self-feed • poor head/trunk control	• dependency • difficult to position/seat	
Communication difficulties • inability to request food/drink • distorted requests • inability to express preferences	• food refusal • distress • fear • irritability • lack of interest • frustration	• attachment affected • limited response to the child • rejection of child/professionals • inflexibility
Maternal state	• anxiety • depression • bereavement • despair	• poor coping strategies

Significance and Consequences of Dysphagia

The consequences of dysphagia can be wide ranging. Subtle defects may go undetected by all but the most experienced diagnostician and may result in minimal impairment for the child. In contrast, the most severe difficulties can result in death due to foreign body entrapment (Carter and Jancar 1983). The long term effects of dysphagia have never been investigated in a longitudinal study of the health and well being of affected patients. It is clear however, that the clinical sequelae of dysfunctional oral and/or pharyngeal function may include repeated episodes of aspiration, recurrent pulmonary infections and possible development of chronic lung disease (Tuchman 1988). In addition, poor nutritional intake may result in protein-energy malnutrition which can in turn affect the immunologic response to infection and adversely affect both physical growth and growth of the central nervous system.

The social aspects of eating can also be severely affected; mealtimes may become something that both the carer and child avoid rather than enjoy (Reilly and Skuse 1992). Eating in public can become a source of embarrassment. The burden of caring for children with dysphagia is great and has implications for both the family and society. Many children require repeated hospital admissions as a consequence of frequent chest infections related to their dysphagia and may ultimately require long term tube feeding.

In the remaining part of the literature review, the discussion will focus primarily on the oral motor skills of both children with cerebral palsy and non-organic

failure to thrive.

Cerebral Palsy

Definition of the cerebral palsies

Many definitions of the term CP have been proposed in an attempt to define a condition in which the causes, mechanisms, presenting patterns of the disorder and brain lesions are multiple. The most recent and comprehensive definition was proposed by Mutch and colleagues (1992) who describe the condition as

> "an umbrella term covering a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of its development".

Although many clinicians and researchers are in agreement as to the definition of CP, there is considerable debate as to how the disorder should be classified. The reason for this is in part historical as the condition was thought to consist of a relatively homogenous group of children whose neurological dysfunction was caused mainly by perinatal factors such as birth asphyxia. However, in recent years it has become apparent that children diagnosed as having cerebral palsy are in fact a highly heterogenous group of mixed aetiology.

Types of cerebral palsy

In describing the cerebral palsies it is necessary to discuss both the type of motor disorder and its distribution. It is important to consider that there is variability in both the type and the severity of CP.

The distribution of the motor disorder is commonly divided into 3 main groups (Hagberg et al 1989);

- quadriplegia and/or tetraplegia
- diplegia and
- hemiplegia.

The terms paraplegia, monoplegia and triplegia are also used occasionally but are thought to occur rarely in CP.

The terms quadriplegia and tetraplegia are sometimes used interchangeably and imply that all four limbs are affected but that the upper limbs may be slightly more involved. Diplegia implies that all four limbs are affected with the lower limbs more involved than the upper limbs. In hemiplegia only one side of the body, either the left or right is affected.

Three main types of motor disorder are commonly described;

- spasticity
- ataxia and
- dyskinesia or athetosis
- rigidity is rather less common but sometimes included in the

topography.

In many instances the type of CP is mixed, for example spasticity and athetosis, although one type may predominate.

Spasticity usually presents a picture of muscle stiffness and fixed posture with a limited range of movement and direction. The voluntary motor patterns are stereotypic with a paucity of movement being obvious. The degree of spasticity varies with the child's condition; for example the child's emotional state, whether they are excited or frightened, may alter the degree of spasticity.

Athetosis is characterised by the presence of abnormal movements or postures, the child often appears unsteady. The coordination of movement and regulation of muscle tone are affected and bizarre and purposeless movements appear to interfere with voluntary activity. The movements may be slow and writhing or fast, jerky and irregular.

Ataxia is characterised by muscular incoordination with poor balance, a staggering gait and general unsteadiness. Tremor may be present.

On the basis of the above description the classification system appears relatively straight forward, however the nature of CP is not. It is rare to find pure forms of athetosis or spasticity, although the condition is nonprogressive, the physical symptoms are known to change over time thus affecting the way

in which a child will be classified. The exact nature of the disability may only become clear when particular motor milestones are reached.

Aetiology of the cerebral palsies

Aetiological factors are commonly divided into three groups:

- pre-natal
- peri-natal and
- postnatal events (Bax 1964, Crothers and Paine 1988).

Although there has been a long held belief that birth asphyxia is one of the major causes of CP, this view is increasingly being questioned. Recent studies suggest that intrapartum insults may be responsible for less than 10% of cases of CP (Blair and Stanley 1988, Richard et al 1989). Bax (1989) suggests that the cause of CP probably remains unknown in approximately 80% of cases.

The main risk factors thought to be associated with CP are summarised in Table 4 and classified according to the aetiology and when the insult occurred; prenatal, perinatal or postnatal. The table is a collation of the results of many studies. Although there are numerous factors listed, the majority are confounded by prematurity which has been found to be the strongest single predictor (Stanley and Alberman 1984). Intracranial haemorrhage in the preterm infant is of prognostic significance (Cooke 1990), however it is not at all clear what determines which infants sustain such haemorrhages and whether prevention is possible in the neonatal period

(Alexander et al 1991). Interestingly, Stanley et al (1987) found that whilst the risk of developing CP was greatest in the preterm infant, during the period of their study 90% of cases occurred in infants of greater than 30 weeks gestation.

Table 4. The most commonly identified causes and risk factors associated with cerebral palsy (Blair and Stanley 1982, 1988).

Aetiology		Risk factors
Prenatal (accounts for the majority of causes of CP, although the exact aetiology in the many cases remains unknown)	• preterm birth • intrauterine growth retardation • brain malformations • genetic factors	**Maternal factors** • diabetes mellitus • threatened abortion • pre-eclampsia • multiple pregnancy • CMV infection • Rubella
Perinatal (probably accounts for less than 10% of all cases).	• birth trauma • asphyxia	Infant factors • intraventricular haemorrhage • ventricular dilatation • chronic lung disease • polycythaemia • hypoxic-ischaemic encephalopathy
Postnatal (accounts for between 5-10% of all cases)	• postconvulsive events • vascular aetiologies	

Prevalence of cerebral palsy

In order to produce prevalence rates researchers depend on the use of one of the schemes so they can decide firstly, what constitutes caseness and secondly, how the case should be classified. The comparison of published prevalence rates (Hagberg et al 1989, Stanley 1979, Pharoah et al 1987) can therefore be complicated by the type of classification system chosen.

Nevertheless, it is generally accepted that the prevalence rate lies somewhere between 1.5 and 2.5 per 1,000 live births (Stanley 1979, Hensleigh et al 1986); rates vary according to the sample studied and when the study was conducted. Published figures apply to industrialised nations only.

The results from 3 international studies comparing the rates of CP, perinatal mortality and birthweight distribution over 3 time periods, 1975 to 1978, 1979 to 1982 and 1983 to 1984, show a consistent trend (Mutch et al 1992). The rate of CP is highest in infants born weighing less than 1500 grams. Since 1975, the number of cases of CP per 1,000 births has increased as mortality has decreased in this extremely premature group. In infants weighing more than 2500 grams mortality has decreased but the rate of CP has remained unchanged. Infant mortality in the 1500 - 2500 gram range has also continued to fall as has the rate of CP (Pharaoh et al 1990).

Classification of the cerebral palsies

The most commonly used classification system is the 'Swedish' model developed by Hagberg and colleagues (1989) and the one adopted in this study to classify the subjects with CP. It has been used increasingly in a variety of studies although not without criticism (Hagberg et al 1989).

Table 5. Swedish classification of the cerebral palsies.

Spastic	■ Hemiplegia ■ Tetraplegia ■ Diplegia
Ataxia	■ Diplegia ■ Congenital (simple)
Dyskinetic	■ Mainly choreoathetotic ■ Mainly dystonic

The most recent attempt to classify the cerebral palsies, The Oxford Standard Recording of Central Motor Deficit (Johnson 1989) includes a checklist for rating associated impairments and is one of the few classification systems to do so.

Major disabilities associated with the cerebral palsies

Whilst the motor disorder is the prerequisite for a diagnosis of CP, there is no doubt that there are a number of associated difficulties/conditions which commonly occur. These may include;

- mental retardation and/or learning difficulties
- disturbances of the sensory system (vision and audition)
- epilepsy
- receptive and expressive language difficulties
- motor speech difficulties

- oral, pharyngeal and oesophageal dysphagia

Dysphagia in Cerebral Palsy.

Aetiology and prevalence

Approximately 39% of developmentally disabled children have been described as having severe feeding problems (Denhoff 1981, Palmer et al 1975) and there is increasing evidence to suggest that some developmentally disabled infants are unable to achieve an adequate nutritional intake because of the severity of their oral motor dysfunction (Gisel and Patrick 1988).

Many of the major studies of the nature and history of CP (for example Crothers and Paine 1988) fail to mention feeding as being problematic. It is therefore not surprising that there are no satisfactory figures relating to the prevalence of feeding problems. Thomas et al (1989) studied a group of adolescents and young adults with CP and found that 56% had major feeding problems. Thirteen had minor problems and 31% had no difficulty. Love et al (1980) administered a series of oral-motor tasks to a population of children with mild to severe CP and found that 40% had abnormalities on at least 1 oral motor task.

However, all these studies have limitations in providing evidence on prevalence and the results should be carefully studied.

- First, the sampling methods used in many studies were poor, for

example some populations are clinical or school samples, increasing the risk of selected populations.

- Second, the definition of what constitutes oral motor dysfunction varies and none of the researchers has used a classification system to attempt to describe the type of problem.
- Third, few studies have administered a test of oral or pharyngeal functioning; the remainder report clinical impressions.
- Finally, an inability to self feed in some studies was also included in the definition of the problem and in one study was the sole criterion.

It is clear that there are no satisfactory data available on the prevalence of oral motor dysfunction in individuals with CP. However, even less is known about the prevalence of pharyngeal dysphagia. This is due partly to the difficulties in diagnosing and accurately assessing the pharyngeal stage of swallowing. One of the few researchers to provide any data was Gisel (1992) who suggested that, whilst very few children with mild oral motor dysfunction aspirated, between 25% and 33% of children with moderate difficulties and approximately 60% of children with severe oral motor dysfunction did. It is not entirely clear how Gisel (1992) obtained these data and nor what her definitions of mild, moderate and severe impairment were. A few remaining studies which are reports of a clinical series of patients do seem to suggest that aspiration is frequent in children and young adults with severe four limb cerebral palsy (Morton et al 1992 and Griggs et al 1989) .

Oesophageal dysphagia is known to occur more commonly. The incidence of gastroesophageal reflux (GOR) is reported to be as high as 75% (Rempel et al 1988) although many of the samples studied have been pre-selected populations. In addition, delayed gastric emptying time (Fried et al 1992) and oesophagitis (Sondheimer and Morris 1979) have also been reported as occurring more frequently. Clinically many professionals and parents report that constipation with abdominal distention and discomfort are commonly seen in children with severe CP.

Characteristics of dysphagia in children with CP

Since There are no satisfactory data on the prevalence of either oral motor dysfunction or pharyngeal dysphagia in children with CP, it is not surprising to discover that there are almost no systematic studies which describe the nature and characteristics of the dysphagia . Children with cerebral palsy can have oral, pharyngeal, oesophageal and/or structural problems. Whilst some may have deficits in just one area others have more complex dysphagia involving all stages of food ingestion. The consequences of oral motor dysfunction can produce pharyngeal dysphagia. For example, some children are unable to form a bolus in the oral cavity which can lead to premature overspill into the pharynx and predispose the child to aspiration or penetration of the material into the airway. This is not regarded as 'true pharyngeal dysphagia' such as that seen in the child with a delayed swallow reflex.

For ease of discussion oral motor dysfunction and pharyngeal dysphagia will be discussed separately. In practise they should never be considered as independent from each other as both stages in the feeding process are intricately linked.

Oral motor dysfunction

There are three aspects to the oral dysfunction observed in many children with cerebral palsy. They are:

- oral motor dysfunction
- oral sensory dysfunction
- oral structure

Most clinicians working in the field are familiar with oral motor dysfunction but often little attention is paid to the sensory or structural aspects.

The traditional description of the difficulties a child with cerebral palsy has with feeding include, excessive tongue thrust, poor lip closure, bite reflex, excessive drooling and food and liquid loss (Morris and Klein 1987, Shepperd 1987, Lewis 1982, Campbell 1979).

However, a quick scrutiny of the literature reveals that the descriptions used have been based on clinical observations alone and then repeated by many authors through the years. Almost every text or paper on feeding problems in cerebral palsy suggests that tongue thrusting is one of the major symptoms

observed. In practice however, the behaviour is not common. In the same way that there is little consensus among clinicians about what developmentally appropriate skills would be observed in children aged between 12 and 18 months, there is even less agreement about what patterns of deficiency might constitute significant oral motor dysfunction. Instead rather general descriptions such as poor lip closure or excessive food or liquid loss are used.

Whilst some children have gross difficulties in managing all the food and liquid textures presented, others have textural specific problems such as not being able to manage hard chewy textures or being able to bite. Gisel (1992) attempted to classify the type and severity of oral and pharyngeal dysfunction in three groups of children with cerebral palsy. The results are summarised in table 6. Beyond clinical experience, little is known about the exact nature of oral motor dysfunction in cerebral palsy. Most clinicians would agree that the children with the most severely affected oral skills are those with spastic quadriplegia or those with bulbar involvement.

Oral motor dysfunction can result in difficulty accepting food/liquid, in sucking, munching and chewing and preparing for and initiating the oral stage of swallowing. The major reasons why these difficulties occur include (Carroll and Reilly 1995):

- poor bolus formation
- poor oral manipulation
- limited tongue movements (may be restricted to immature sucking or

squashing movements)

- limited or no jaw stabilisation
- inability to create negative pressure inside the oral cavity to collect up food/liquid
- inability to close jaw/lips
- no lateral tongue movements
- no rotary or lateral jaw movements

Table 6. Classification of oral motor dysfunction in children with cerebral palsy, a summary of Gisel's findings (Gisel 1992).

Severity of oral motor dysfunction	**Mild**	**Moderate**	**Severe**
Duration of feeding cycle	may take twice as long to finish a meal	meal-time prolonged++	Takes 10 times as long to eat a meal
Food texture	manages purée adequately significantly more difficulty with solids	manages solids well, significantly more difficulty with purée the thinner the food the greater the difficulty	difficulty with all food textures. oral motor skills at most rudimentary level
Management	provide extra eating time-conventional management strategies	sensori-motor therapy can be effective	complementary feeding via nasogastric tube or gastrostomy is often necessary

In order to obtain the most comprehensive view of the child's oral motor function and manage the resulting difficulties, any evaluation must incorporate

a range of textures. In table 7 (adapted from Carroll and Reilly 1995) the common difficulties many children with cerebral palsy have with different textures are outlined.

Table 7. Common oral motor difficulties experienced by children with cerebral palsy (Carroll and Reilly 1995)

Texture	Type of difficulty
Liquids or thin purées	• spreads around the mouth • pools under the tongue • incomplete collection (negative pressure) • premature over spill (posterior drooling) • lack of/incomplete jaw stabilisation • lack of/incomplete lip closure • excessive liquid loss (anterior drooling)
Semi-solids (discrete soft lumps)	• food spreads around the mouth • lumps with skins (e.g.peas/beans may be particularly difficult) • food is not munched but lumps swallowed whole • food squashed against alveolar ridge • gagging and choking
Solids (defined hard lumps)	• no lateral jaw or tongue movements • lumps are spat out • swallows lumps whole • lumps remain stationary on tongue • lumps are manipulated but not masticated

Little is known about oral sensory deficits in children with cerebral palsy. There is no doubt that sensory feedback is crucial to oral function. Without finely tuned sensory feedback, it would be impossible to bite or chew without constantly biting the tongue, lips or gums. All aspects of eating and drinking behaviour are affected. Some children with cerebral palsy suffer from oral

sensory deficits because of oral deprivation. During critical stages of hand to mouth development they are unable to experience the mouthing activities that normal infants undergo. Subsequently, some children are resistant to oral play, tooth cleaning etc. Others may have had prolonged periods of nasogastric feeding, which affects the development of their oral skills (Morris 1989). In such cases children may not have had the chance to learn particular oral skills and when fed have no idea how to manipulate or prepare food for swallowing. Developing a sensitivity to oral stimulation of any sort and a resistance to oral feeding is not uncommon.

Studies of children with spasticity have shown an increased incidence of malocclusions. Malocclusions increase with age (Sandler et al 1974) and cross bites are more common in children with hemiplegia (Koster 1956). More recently Pelegano et al (1994) ascertained that contractures of the temporo-mandibular joint were more common in children with spastic quadriplegia. Interestingly, the severity of these abnormalities correlated with the degree of oral motor dysfunction. Furthermore, the degree of overbite, found to be the most important parameter, correlated with the severity of the oral motor problems, such as loss of food and liquid, coughing and choking, respiratory infections, snoring and snorting, adverse mealtime behaviour and the presence of reactive-airway disease. The authors suggested that temporo-mandibular contractures were detrimental to oral feeding; it remained to be discovered whether these contractures were a cause or effect of the oral motor dysfunction.

Pharyngeal function

Symptoms such as gagging, coughing and choking are often signs that children are experiencing pharyngeal difficulties, however, some show no outward signs of difficulty yet are shown to aspirate (Griggs et al 1989). The "gold standard" technique for diagnosing such difficulties is the modified barium swallow or videofluroscopic examination. The technique is also extremely valuable for ascertaining which management strategies are useful in reducing aspiration or penetration.

A number of problems with the pharyngeal stage of swallowing have been highlighted by different researchers (Wolf and Glass 1992, Griggs et al 1989, Morton et al 1993). Table 8, adapted from Carroll and Reilly (1995) illustrates the most common problems.

Table 8: Pharyngeal dysfunction: Common problems.

Common problems with the pharyngeal stage of swallowing
■ Delayed swallow reflex
■ Aspiration before the swallow
■ Aspiration during the swallow
■ Aspiration after the swallow
■ Premature pharyngeal overspill
■ Pharyngeal residue
■ In-coordination between the swallow and ventilatory cycle
■ Nasal regurgitation

Despite the limited information available regarding oral and pharyngeal dysfunction in children with CP, clinical evidence suggests that many have major problems ingesting food, rendering them extremely difficult to feed.

Significance and long term consequences of dysphagia in children with CP

The consequences of Dysphagia were summarised in table 3. There is considerable morbidity and mortality secondary to dysphagia; recurrent aspiration with secondary infection and injury to the developing lung is not uncommon. In a population of severely retarded institutionalised clients, many of whom had CP, the most common cause of death was respiratory tract infections which accounted for approximately 46% of all deaths (Carter and Jancar 1983). The second most common cause of sudden death (accounting for 15% of total deaths) was non-epileptic asphyxia; patients at

highest risk for non-epileptic asphyxia were those with feeding abnormalities who also took tranquillisers (Carter and Jancar 1983).

The long term effects of malnutrition as a result of an inability to achieve an adequate oral intake are widespread and include (Stevenson et al 1994, Stallings et al 1993):

- reduced immune response
- reduced muscle strength
- prolonged circulation time and low cardiac output
- oesteopenia
- reduced attention span and learning ability
- decreased motor ability
- increased irritability

The relationship between oral motor dysfunction and associated disabilities

The severity of oral motor dysfunction is related to other aspects of the child's development including:

- Motor function.

  By definition children with CP will have varying degrees of motor handicap as a result of abnormalities of posture, tone and movement. These abnormalities are influenced by the persistence of primitive reflexes which may be exaggerated in children with CP. As a result undesirable head, neck and trunk postures develop which can interfere with function. For example, a persistent asymmetrical tonic neck reflex

can result in typically fixed postures of the head, neck and upper extremities which severely limit oral feeding; there may be excessive loss of food/liquid, an increased risk of aspiration and poor bolus control as a result of tongue and jaw extension. An inability to stabilise the head and neck can alter the patency of the airway and further affect the respiratory mechanism, oral control and swallowing function.

- Cognition:

  Many researchers have shown that the more severe the CP the higher the incidence of associated abnormalities such as cognitive deficits and oral motor dysfunction (for example, Christensen 1989). Therefore they conclude that children with oral motor problems are more likely to have cognitive impairments which has implications for the type of intervention programme that can be initiated. The initiation of self feeding and goals for the development of any feeding skills must therefore take into account the developmental status of the child. Although the development of oral feeding in non-disabled children seems to occur in a consistent, stepwise manner, development in children with abnormal motor and sensory systems may or may not follow this sequence as the skills are being acquired by a child with an impaired nervous system.

- Communication:

  Children with severe motor speech deficits such as those seen in

children with CP may have extreme difficulties in communicating even their most basic wishes and needs (Carroll and Reilly 1993). They may have impaired expression of hunger and thirst particularly if they have experienced long periods of nasogastric or gastrostomy feeding. Others may not be able to signal satiety or indicate that the food is too hot or too cold. They may also be unable to communicate their likes and dislikes or may not be given the opportunity to do so. Many children with severe speech difficulties are dependent on an adult feeder to interpret their communication attempts; whilst some carers are particularly sensitive to their child's needs others may find the child's cues harder to read. Creating opportunities for communication during mealtimes can prolong the meal and requires extra effort on the part of the carer; consequently many carers may be unable to respond to this additional demand.

- Behaviour:

  Although behaviour problems are thought to be 5-6 times more common in children with CNS damage (Rutter et al 1970), there are few data on feeding related behaviour problems in children with CP. Many have had negative experiences related to feeding such as tube feeding, intubation and frequent suctioning. Episodes of coughing, choking, gagging and aspiration may be frequent and unfortunately some carers and professional staff resort to force feeding in an attempt to achieve an adequate intake (information obtained via parental

interviews). The child with CP is limited in how he/she can respond, because of the nature of the motor disorder and the possibility of communication impairments. Food refusal and excessive spitting are commonly seen. Some children present with a tongue thrust which is only evident at mealtimes, and perhaps only with specific food textures and tastes. This may reflect in part their difficulties in communicating their displeasure, and they resort to the use of such behaviour to communicate.

Failure to thrive

In recent years clinicians have become aware that some children with failure to thrive have undetected oral motor dysfunction.

Definition of failure to thrive

Failure to thrive was defined by Skuse (1985) as abnormally low weight and/or height for age. Whilst in some children there is an identifiable organic aetiology (endocrine deficiencies, congenital or genetic anomalies) in others there is none. The term non-organic failure to thrive is therefore often used to describe those children with no obvious identifiable cause underlying their growth failure.

Skuse et al (1992) developed a set of criteria to define the cases seen in the study. The criteria pertaining to the definition of non-organic failure to thrive included :

- full term singleton births (> 38 weeks gestation)

- no severe intra-uterine growth retardation (birth weight above the 3rd population centile on charts standardised for gestation, sex, ordinal position, maternal height and mid-pregnancy weight).
- weight for age at or below the 3rd population centile, this growth trajectory having been sustained for at least 3 months.
- premature and low birth weight babies were excluded because of the known association with below average postnatal growth.

Aetiology of failure to thrive

The early literature on failure to thrive suggested that the disorder was primarily due to maternal rejection and neglect (Patton and Gardner 1963). However, as Skuse et al (1994) suggested there has been relatively little discussion of the mechanisms by which this may occur. The origins of failure to thrive seem to be rather more complex than originally proposed and more than likely involve an interaction between both child and family variables. However, more recent evidence suggests that there is increasing support for the view that undernutrition might be one of the main causes (Skuse 1985). Two possible reasons were proposed that might account in part for the undernutrition; first, that the children did not receive adequate nutrition from their primary caretaker and second, the presence of oral motor dysfunction could prevent them from achieving a satisfactory nutritional intake.

Lewis (1982) proposed that oral motor dysfunction could contribute to failure to thrive in infancy. She described difficulties such as sucking, chewing and tonic biting of the spoon as well as intolerance of developmentally appropriate textures. Lewis felt that such difficulties led to prolonged mealtimes and inappropriate contextual features. Heptinstall et al (1987) discovered that half of the 4 year olds with chronic growth retardation had some disorder of oral motor function. In addition, on studying the growth records of the children they found that nearly all the 4 year olds had begun to fail to thrive in the first year of life.

In order to further explore this finding, Mathisen et al (1989) studied a group of 9 one year old infants with non-organic failure to thrive and compared them to a comparison group of healthy children. The findings showed that the case infants had oral motor dysfunction associated with developmental delay. The oral motor dysfunction was felt to be similar to that seen in neurologically impaired infants. In a more recent study Ramsey et al (1993) saw 38 infants with non-organic and 22 with organic failure to thrive. They found that the histories of the children with so called non-organic failure to thrive were suggestive of an oral sensorimotor impairment which was usually present from birth or early infancy and tended to go unrecognised. Furthermore, Ramsey and colleagues suggested that the children were 'minimally neurologically abnormal', that is although no diagnosis had been given, the children had histories and current development suggestive of minimal neurological impairment. The findings of Ramsey and colleagues (1993)

seem to add support to the theory that a proportion of children have subtle neurological abnormalities which are reflected in their oral motor functioning.

The concept of failure to thrive has undergone some radical changes since it was first suggested in the 1940's that it was caused by emotional deprivation. Current thinking suggests that the term non-organic failure to thrive should be revised as many of the children may in fact have an underlying but not readily identifiable cause. Certainly, undernutrition would seem to account for a proportion but not all cases. It is possible that a number of subgroups exist, each of which may be attributable to a different aetiology or combination of aetiologies.

Prevalence of failure to thrive

In the community study conducted by Skuse et al (1994) there were 1,554 potential subjects. Fifty-two cases (3.3%) of failure to thrive were identified when the children were 12-15 months of age. Only 3 cases were found to have a recognizable organic disorder accounting for their poor growth. Forty-nine cases of NOFT were diagnosed after full paediatric and neurological examination, resulting in a prevalence rate of about 3.15% who failed to thrive in the first year.

Dysphagia in failure to thrive

There have been very few studies of the oral skills of children who are failing to thrive from causes other than cerebral palsy. Selley and Boxall (1986) described 'incoordination of the feeding mechanism' as a cause of failure to thrive. Lewis (1982) described a number of specific symptoms including sucking, swallowing and chewing difficulties as well as tongue thrusting, involuntary tonic biting of the spoon or nipple and excessive drooling. The study by Mathisen et al (1989) was the first to administer an assessment of oral motor functioning in order to describe and quantify the children's function. They found that there were significant differences between the case and comparison children's abilities to effectively manage both purée and solid textures but not semi-solids. The children with failure to thrive had higher abnormality scores on both these textures. In addition, there were striking differences in the children's oral tone; 6 of the 9 case infants as opposed to 2 of the comparison infants had hypotonic lips. Furthermore, there were also significant differences in the infant's response to tactile stimulation. The results were however, obtained on a small sample of infants identified by health visitors and there was almost certainly bias in how the infant s were selected.

The more recent study by Ramsey et al (1993) did not include an assessment of oral motor functioning. The histories taken however, were suggestive of a history of oral motor dysfunction. For example, there were high proportions of

children with an abnormal duration of feeding times, poor appetite, delayed texture tolerance and difficult feeding behaviour. A history of sucking difficulties was also common.

From the few available reports, there is increasing evidence that a proportion of children previously described as having non-organic failure to thrive might have specific oral motor dysfunction. These findings are significant for a number of reasons; first because the the manner in which so called non-organic failure to thrive, is managed would be radically different. The treatment approaches adopted so far have concentrated primarily on the family dysfunction and mother-child interaction. Second, it would be of great interest to ascertain exactly what proportion of children with non-organic failure to thrive might have oral motor dysfunction. Finally, if the findings could be replicated and verified then the manner in which the disorder is classified would also need to be modified as such children could no longer be thought to have 'non-organic failure to thrive'.

Evaluating dysphagia

Methods of assessment

The literature review has so far demonstrated that there is limited information about the development of oral motor function during infancy and early childhood. Not surprisingly then, very few methods of assessing oral and/or pharyngeal function in infancy and early childhood exist and none is satisfactory or comprehensive.

Methods are available for assessing dysphagia in adults with acquired neurological disorders or structural problems (Dworkin and Culatta 1980, Price et al 1987, Enderby 1983, Logemann 1983). Administration of such assessments to children would at best provide limited information and perhaps worse, misleading or incorrect information. Such assessments were developed for the mature oral motor system; abnormal performance on a particular test may represent a deficit in an adult but age appropriate performance in an infant or young child.

The early development of sucking and swallowing in young infants has been well documented (Adran et al 1958, Doty and Bosma 1956, Bosma 1957, Weber et al 1986, Wolff 1968) and a number of studies have suggested that early feeding behaviour is a sensitive indicator of central nervous system integrity in neonates (Kron et al 1966, Brazleton 1970, Dreier et al 1979, Hill and Volpe 1981, Casaer et al 1982). In order to provide an objective method of rating the acquisition of these skills, Leaf and Gisel (1986) developed an observation method for analysing sucking and Braun and Palmer (1985) developed the Neonatal Oral Motor Assessment Scale (NOMAS); however both are only applicable to the neonatal population. Other researchers (Weathers et al 1974, Kron et al 1963, Selley et al 1990, Vice et al 1991) have developed a variety of techniques and used innovative equipment to assist in the evaluation of early sucking and swallowing behaviour during infancy but are not practical tools which can be used in a clinical setting.

Although methods for assessing children's oral motor functioning do exist (Vulpe 1969, Campbell 1979, Sleight and Niman 1984, Morris 1982, Stratton 1981, Shepperd 1987, Kenny et al 1989, Gisel and Patrick 1989), they all have limitations. In general, the early literature is descriptive, discussing the development of oral motor skills and highlighting areas to be included in an evaluation; 'feeding checklists' have been developed primarily for use with disabled children, such as those with CP (Ogg 1975, Lewis 1982).

The Pre-speech Assessment Scale (PSAS) developed by Morris (1982b) is the most comprehensive scale developed to date. The PSAS examines control of oral secretions, eating, pre-speech vocal behaviours, and early speech development in developmentally disabled infants and children. The PSAS norms on which the scale is based are extremely limited; Morris (1982) studied the development of feeding patterns in 6 normal children at intervals of 3 months from 12 to 24mths. Furthermore, the scale suffers from the serious limitation that judgements about what are 'normal' and 'abnormal' behaviours at specific ages are based on norms that are derived from an inadequate sample. The reliability data, calculated upon percentage of agreement among therapists, ignores the extent of agreement by chance and is therefore inadequate (Berk 1979).

Kenny et al (1989) developed a multidisciplinary profile for use with dependent feeders which they demonstrated was of good reliability. The profile is divided into 6 sections: physical/neurological, oral-facial structure,

oral-facial sensory inputs, oral-facial motor function, ventilation/phonation and functional feeding assessment. It is designed to be administered by a range of different health professionals, in a variety of settings and takes approximately 45 minutes to administer. The profile was designed for developmentally disabled children and pilot tested on 8 such subjects who were dependent feeders. Kenny et al (1989) considered dependent feeders to be the most functionally disabled individuals and those most likely to be considered for nonoral feeding methods. No details are given as to how the individual items were selected for inclusion in the profile and no normative data presented.

Stratton's (1981) 'Evaluation of Oral Function in Feeding' measures a limited number of skills, was not standardised on normal children and has been shown to have marginally acceptable reliability (Ottenbacher et al 1985). Sheppard (1987) developed a model for the Pre-school Oral Motor Examination, to be used by clinicians working with children with CP and various other populations of at-risk infants. There are 8 sections to the examination which include the history, peripheral speech-mechanism examination, oral reflexes, oral postural control, control of oral secretions, eating, voluntary, nonverbal behaviours and vocal behaviours. No details are given regarding normative data or reliability.

Gisel and Patrick (1988) developed a scale of 14 abnormal oral-motor behaviours and compared the performance of children with CP with weight-aged matched controls. Two textures of food were used, purée and solids.

Although the authors used a comparison group of normal children for some measures, no normative data or measures of inter-rater reliability were provided. Vulpe's (1969) Developmental Feeding Assessment Scale scores children's abilities in different domains of eating but does not lend itself to the quantification of specific oral motor behaviours.

In summary the paediatric oral motor assessments currently available have a number of limitations;

- First, they were developed primarily for use with a neurologically impaired population and therefore cannot easily be applied to infants with an intact neurological system or with relatively minor degrees of dysfunction. Recent research has shown that oral-motor dysfunction in infancy is not limited to those with neurological disorders (Mathisen et al 1989, Mathisen et al 1992, Sonies 1990).
- Second, they do not assess oral motor behaviours in a standardised manner using a variety of food textures; texture has been shown to be an important factor affecting the oral motor performance of infants and young children.
- Third, norms have not been established on the developmentally appropriate oral motor skills of neurologically intact subjects during infancy and early childhood.
- Finally, there is no known instrument with reported reliability that has been validated both on a sample of normally developing infants and applied to different clinical groups (Ottenbacher et al 1985, Kenny et al

1991, Berk and DeGangi 1979).

Therefore, there is an urgent need for the development of a valid and reliable measure of oral motor functioning in children. Such an instrument should fulfill a number of basic criteria which include;

- be applicable to a relatively wide age range of young children,
- incorporate the rating of exposure to a range of food textures,
- have established norms standardised on children with normally developing oral motor skills,
- be a reliable instrument capable of being administered by a variety of therapists
- be applicable to a variety of clinical groups including children with gross oral motor deficits occurring as a result of neurological dysfunction and to children with more subtle deficits where the aetiology is less clear.

Because the ingestion of food and liquid is such a complex process a thorough evaluation will ensure that a variety of assessment tools should be used to examine the 4 stages of eating and drinking.

Chapter 3

Summary and aim of the study

The review of the literature indicated an almost wholly descriptive approach to oral motor development and dysfunction in infants and young children. There is considerable morbidity and mortality secondary to dysphagia. Despite this no satisfactory method with established reliability and validity exists for evaluating one of the most crucial stages of feeding.

The main aim of this study was to develop an instrument capable of objectively rating oral motor function in children aged between 6 and 24 months.

Research Hypotheses

- Children with cerebral palsy are likely to have clinically significant oral motor dysfunction. It is hypothesised that The Schedule for Oral Motor Assessment (SOMA) will be a sensitive instrument capable of identifying these children and discriminating them from children with normal oral motor function.
- Children with non-organic failure to thrive have subtle, but significant oral motor dysfunction of unknown aetiology. It is hypothesised that the SOMA will be sensitive enough in identifying such children and discriminate them from children with normal oral motor skills and those with more severely impaired oral motor skills.

- It is hypothesised that some of the textures used in the SOMA will be more sensitive than others in identifying abnormality. Children with cerebral palsy will perform poorly on all textures whereas those with non-organic failure to thrive will have textural specific oral motor dysfunction.

Aims

The specific aims of the study include:

- First, to develop an instrument capable of objectively rating oral motor function in infants aged between 6 and 24 months.

- Second, to determine the reliability of the instrument. In order to be of clinical value the assessment will be considered first, in terms of the repeatability of the child's behavior or test-retest reliability. Reliability will also be measured in terms of whether independent raters agree on the rating of a behaviour on the same occasion.

- Third, to establish the vailidity of the instrument by ascertaining if it is capable of identifying children with clinically significant oral motor deficits and discriminating them from children with normal oral motor function.

- Fourth, to further validate the instument on an independently collected sample of children with known oral motor deficts.

- Finally, to develop a screening version of the SOMA which can be used clincially to detect children with significant oral motor dysfunction and for research purposes to screen whole populations.

The following chapters are organised into 2 main sections which reflect the design of the study. Chapter 4 concerns the development of the instrument the methodology used and the results. Chapter 5, entitled the Validation Study, concerns the further validation of the SOMA on an independent sample of children with cerebral palsy.

Chapter 4. The development study

Introduction

This chapter is divided into 2 sections. Its organisation reflects the design of the study.

- Part one contains a description of the development study. It describes the methodology developed, the procedures adopted, an outline of the data analysis and a summary of the major findings. This section aims to familiarise the reader with the instrument and the methodology as they are directly relevant to chapter 6, the validation study. Three papers are submitted in appendix 1 (Reilly and Skuse 1992, Reilly et al 1995 and Skuse et al 1995). They describe in detail the selection of subjects, development of the instrument and the validation methods used in the study.

- Part two, describes the results of the development study.

Part 1

Study design and description of samples:

The development study was carried out by a number of researchers. The author, in collaboration with these researchers, had a major contribution to the development study. The author was responsible for the collection of all data pertaining to the children's oral motor skills; this included administration of more than 90% of the assessments, rating from video and scoring of all 127 oral motor assessments. In addition, the responsibility for data entry and coordination of data analysis rested with the author. Data analysis was undertaken with the generous assistance of Dr Jim Stevenson, Miss Sally Baxendale and Professor David Skuse. In collaboration with colleagues, the Schedule for Oral Motor Assessment (SOMA) was developed.

Study design

Three groups of children were studied.

- A comparison group consisting of children with normal growth trajectories and normally developing oral motor skills. These children were included to provide a standardisation sample.
- A group of children with non-organic failure to thrive (NOFT). The results of previous work (Skuse et al 1992, Mathisen et al 1989) suggested a substantial proportion of these children would have either immature or deviant oral motor skills.
- A group of children with a confirmed diagnosis of cerebral palsy. These

subjects were selected because they had overt feeding difficulties associated with their neurological deficits.

Description of sample

The data were from a sample of 127 children which included 58 normally developing infants (the comparison group), 56 children with non-organic failure to thrive (NOFT) and 13 children with cerebral palsy (CP). The children ranged in age from 8 to 44 months. The mean age of the comparison group was 12.2 months (range: 8 - 21.2 months), the NOFT children 15 months (range: 8.75 - 19.5 months), and the children with cerebral palsy, 20.2 months (range 14.2 - 44 months).

Identification of subjects

The children in the NOFT and comparison groups was selected largely from an inner-city (population circa 140,000) whole population survey of 1558 full term singletons, born between 1st January and 31st December 1986, who were registered with participating child health clinics or family doctor practices. The growth of 2,510 infants who attended participating health clinics and group practices for weighing and developmental checks and who remained living in the district through the first year of life were monitored (Skuse et al 1992). Detailed information about the design of the prospective community study, such as sample selection and characteristics of the children, can be found in a variety of publications (Mathisen et al 1989, Skuse et al 1992, Skuse et al 1993, Skuse et al 1994).

NOFT infants:

The final sample of NOFT infants (n=56) was drawn from 2 studies. The first a pilot study investigating failure to thrive in infancy (Mathisen et al 1989) and the second, a community study of failure to thrive (Skuse et al 1992, Skuse et al 1993, Skuse et al 1994). Both the community and pilot study of failure to thrive, identified subjects whose growth faltered in the first 12 months of life. Subjects were selected according to strict criteria (Skuse et al 1992) which included:

- full term singleton births (> 38 weeks gestation)
- no severe intra-uterine growth retardation (birth weight above the 3rd population centile on charts standardised for gestation, sex, ordinal position, maternal height and mid-pregnancy weight (Tanner 1989).
- weight for age at or below the 3rd population centile, this growth trajectory having been sustained for at least 3 months (Tanner and Whitehouse 1984).
- premature and low birth weight babies were excluded because of the known association with below average postnatal growth (Brothwood et al 1987).

In the community study there were 1,554 infants whose birth weights were at or above 2,500 grams and whose gestation was 38 weeks or more. Fifty-two cases (3.3%) of failure to thrive were identified at 12-15 months of age. Only 3 cases were found to have a recognizable organic disorder accounting for their poor growth. Forty-nine cases of NOFT were diagnosed after full paediatric and

neurological logical examination. Full details are given in Skuse et al (1992). A further 9 cases of NOFT were included in the sample. These children were recruited during the pilot study (Mathisen et al 1989).

Comparison infants

The comparison group (n=47), was chosen from the population database, and matched to the 47 confirmed cases of NOFT on the basis of, sex, age, ethnic origin, birth weight (to within 300 grams), ordinal position and socioeconomic status. A further 11 comparison subjects were recruited during a pilot study for the same investigation (Mathisen et al 1989, Skuse et al 1992).

Children with cerebral palsy

Preschool children with a confirmed diagnosis of cerebral palsy and a significant degree of oral-motor dysfunction were identified from attenders at specialist clinics within the Greater London area. Paediatricians were contacted with a view to identifying a pilot sample under the age of 48 months. Thirteen children were referred and subsequently recruited. Inclusion criteria included:

- a confirmed diagnosis of cerebral palsy
- aged less than 48 months
- the paediatrician nominated the child as having a significant degree of oral motor dysfunction
- the carers stated that the child had a major feeding problem.

The children formed part of a pilot study investigating the characteristics of

feeding behaviour in preschool children with cerebral palsy (Reilly and Skuse 1992 in appendix 1).

Recruitment of subjects

The manner in which each of the samples was recruited is fully described in Reilly and Skuse (1992), Reilly et al (1995) and Skuse et al (1995) in appendix 1.

Procedure

The same procedure was adopted for each sample. Each family was visited at home and data were usually collected during one home visit, although occasionally two visits were necessary. Because the NOFT and comparison children were part of larger studies investigating different aspects of growth and development the families were visited by 2 other researchers and a number of instruments and interviews were administered. The visit concerned with feeding was usually the last home visit and comprised three parts;

- first, a semi-structured feeding interview with the child's primary caretaker, in most cases the child's mother.
- second, a video recording of the child's main meal of the day was made and
- third, the Schedule for Oral Motor Assessment (SOMA) was administered.

Instrument Design and development

The SOMA will be discussed in detail; other procedures have been described in earlier publications (Mathisen et al 1989, Mathisen et al 1992, Skuse et al 1992, Reilly and Skuse 1992) and are not relevant to this thesis.

Development

The development of the SOMA is described in Reilly et al (1995) in appendix 1. The following description will therefore concentrate on familiarising the reader with the instrument, the procedures for administration and the main components. The SOMA was developed to fulfil two purposes; first, to enable the objective recording of oral motor skills in infants between the ages of 8 and 24 months. Second, to use the assessment to evaluate oral motor function in children with either no overt neurological dysfunction or those with minor degrees of dysfunction. Because preexisting oral motor assessments had been developed primarily for use with individuals who had severe oral motor dysfunction resulting from neurological impairment, they were not applicable to the infants chosen in this study. As has already been highlighted no valid instrument with known reliability existed.

During the development phase it became clear that the SOMA should meet a number of basic requirements:

- First, it was essential that the child's oral motor skills should be challenged with a variety of textures. Although developmental trends in the normal process of oral motor skill acquisition following the introduction

of mixed feeding had been noted by various researchers, the process was not adequately described. Variation was noted in both the age at which the infant's first solids were introduced and when foods of increasing texture were offered to infants. Some infants will therefore have had a wide range of oral motor experiences with exposure to a variety of different tastes and textures while others may have had rather limited experience.

- Second, the manner in which the food and liquid were presented should be standardised. Recent evidence confirmed that oral motor performance varied according to the texture or implement used during feeding. Our own experience during pilot work showed that the way in which some mothers fed their children affected their oral motor performance. For example, they tended to tilt the spoon upwards when withdrawing it from the child's mouth, thus enabling the child to remove the food more easily. In addition, they often used the spoon to clean their children's lips of any remnants of food. This resulted in the rater being unable to observe either the child's ability to remove food from the spoon unaided or the combined action of the lips and teeth to clean the lips.

- Finally, the need for a standard set of feeding utensils was established. As a result of pilot work it became clear that the use of ordinary opaque plastic utensils was not ideal. It was often difficult to observe some oral motor behaviours and to ascertain if indeed the food had been removed

from the spoon or liquid taken from the cup. Accordingly, in conjunction with a manufacturer of infant feeding equipment (Cannon Babysafe), a standard set of feeding utensils was developed (spoons, bottles, cups and teats). The utensils were constructed of clear non-breakable plastic so that lip and tongue movements were clearly visible as was the amount of liquid in the bottle or cup. The design of the equipment resembled that commonly used by children in the 12-18 months age range. Examples of the equipment are shown in the photograph enclosed in appendix 2.

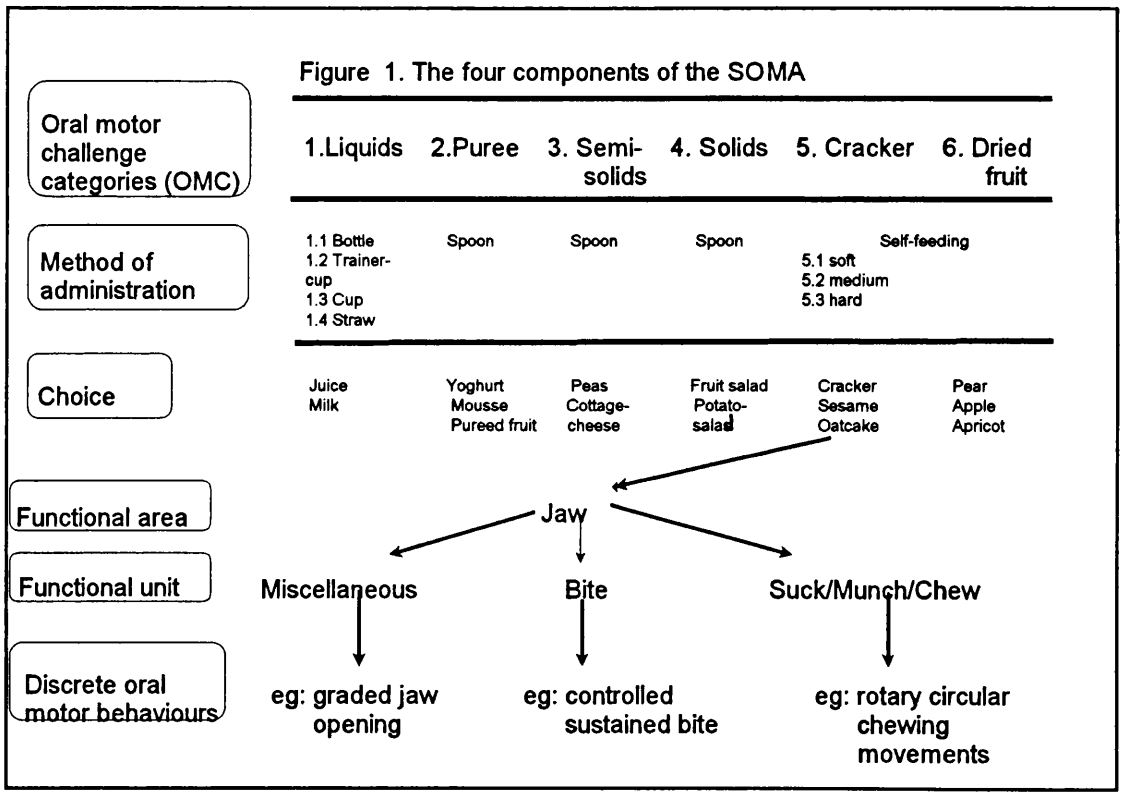
Administration

The SOMA was administered to each child approximately 1-2 hours after their main meal, in most cases lunch. The examination took on average 20 minutes. All SOMA procedures were video recorded using a JVC colour camera (Newvicon) which was either hand held, supported on a table or mounted on a tripod. Natural lighting was used. The camera was sensitive to low light conditions (15 lux), had a built in stop watch, a powerful zoom facility, automatic exposure control and automatic focusing. The assessment procedure was filmed by the mothers following a brief demonstration and practice session; they were positioned so that the view of the child's head and neck was taken from an oblique angle. The examiner was positioned in front of the child so that all food was presented in the midline. The assessment was administered according to strict criteria developed by the author and explained in full in the administration and scoring manuals (Reilly 1987 - unpublished data available from the author) (see appendix 3 and 4).

Structure

The schedule is divided into four levels. The following schematic diagram (figure 1) from Reilly et al (1995) gives details of the structure of the SOMA.

Figure 1: The four components of the SOMA are shown: the oral motor challenge categories (OMC), functional areas, functional units and the discrete oral motor behaviours (DOM).



Each of the four levels will be briefly described.

Oral motor challenge categories

Oral motor challenge categories (OMC) refer to the texture of the foodstuffs/liquids presented. They included;

- **Liquids**
- **Purée**
- **Semi-solids**
- **Solids**
- **Crackers**
- **Dried fruit**

A series of oral motor challenge categories, administered in a structured manner, using standardised amounts of food and liquid were chosen. Each child was fed standardised quantities of the foodstuffs/liquids. Liquids were assessed during breast or bottle drinking (OMC-1.1) , drinking from a trainer cup (OMC-1.2), a cup without a lid (OMC-1.3) and from a straw (OMC-1.4). Purée (OMC-2), semi-solids (OMC-3) and solids (OMC-4) were spoon fed by the examiner. The crackers (OMC-5) were finger fed by the examiner where possible as was the dried fruit (OMC-6). The foodstuffs were chosen on the basis that most infants in the 6-24 months age range should be capable of coping with the majority of them satisfactorily but that varying degrees of oral motor expertise would be required. The procedure was piloted extensively in order to determine which foods were socially and culturally acceptable to a wide range of infants. The piloting procedures are explained more fully in Reilly et al (1995) in appendix 1

.

Functional areas

Functional areas refer to the muscle group(s) or structures being investigated:

- **Head and trunk control**
- **Lips**
- **Tongue**
- **Jaw**

Functional units

Functional units describe the activity the muscle group(s) or structures perform, such as, the role of the lips in preventing food loss during eating. Those shown below refer only to one oral motor challenge category, purée. The number of functional areas varies according to the oral motor challenge category.

- **Refusals**
- **Reactivity**
- **Acceptance**
- **Initiation**
- **Food loss/Drooling**
- **Sequence/Rhythm**
- **Suck/Swallow**

Discrete oral motor behaviours

DOM behaviours are the individual motor movements made by the muscles or structures. There may be many discrete oral motor behaviours involved in one functional unit. For example, to prevent food loss during eating, a number of behaviours are involved. First, the upper lip moves down to assist in removing food from the spoon, second the lower lip seals around the spoon, third, the

upper and lower lip close to form an anterior seal. In addition, they combine with the action of the tongue and mandible and move to keep food within the mouth, rescue pieces of food remaining on the lips or clean the lips of any remnants of food. More detail is available in Reilly et al (1995). A complete list of the DOM behaviours are shown in Reilly et al (1995) in appendix 1. Illustrated below are just a few examples of discrete oral motor behaviours.

- **anticipatory mouth opening**
- **25% or more food lost**
- **extension-retraction movements of the tongue**

Trials

A decision was made to administer three trials of each OMC category because there was no clear evidence to indicate whether the oral motor performance of infants and young children was consistent from one feeding session to the next. In addition, the effect of feeding challenging textures, that is, ones outside the child's usual range of experience, had not been established. These three trials were administered by the examiner and followed by a fourth trial during which the infant was given the opportunity to self feed. There were a number of advantages to the examiner administering the main trials to the child. It ensured that a standard presentation without undue assistance was achieved and in addition permitted the making of a number of on-the-spot ratings of oral motor behaviours, such as tongue function, which could not have been seen on the

videotape. Occasionally, children refused to be fed by the examiner and in such situations the mother was given instructions and a demonstration of how to present the food. There was a suitable pause between each mouthful and the child's mouth was checked by the examiner in order to ensure the child had swallowed and that no remnants of food remained in the oral cavity. At least two choices of food were available for each OMC category (see Figure 1). Mothers were asked to indicate which choice of food she thought her infant would prefer. If the infant refused or showed dislike to the first food, the alternative was offered.

Scoring

A scoring manual was developed to ensure that ratings could be reliably made. The manual (included in appendix 4) describes each behaviour in detail and the manner in which it should be rated (Reilly et al 1987). Each discrete oral motor behaviour in each of the 7 oral motor challenge categories was rated, resulting in approximately 700 behaviours. All ratings were done from video recordings apart from some on-the-spot ratings which had been recorded during the session.

A number of scoring categories were developed to deal with behaviours that could not easily be rated. Two dimensions were used;

- first, if a behaviour was observed it was deemed rateable and
- second if a behaviour was not observed it was deemed not rateable.

Not-rateable responses included: child refusals, items that were omitted and items which proved exceptionally difficult to rate. Omitted items occurred very occasionally, in most cases because of technical difficulties or if there had been an administration error. Some DOM behaviours were not-rateable because they were not easily observed, such as lateral tongue movements. A full description is given in Reilly et al (1995) in appendix 1.

Rateable responses were scored dichotomously, according to whether the behaviour was present or absent. Each DOM behaviour was rated individually. All three trials of each of the 7 OMC categories were rated, resulting in a minimum of at least 75 DOM behaviours that were rated for each trial and not less than 225 behaviours rated for each OMC category.

Data analysis - plan and procedures

Plan

The three groups of children were used for specific purposes. Whilst the comparison subjects were clearly a control group with normally developing oral motor skills, a proportion of children with NOFT were expected to have some oral motor deficits. In contrast, the children with cerebral palsy were chosen specifically because of their known oral motor skill deficits and therefore used as validating criteria for the instrument. Before proceeding with data analysis it was crucial to define the status of each individual behaviour.

Procedures

Defining abnormality

For the purposes of the validation exercise it was necessary to make decisions regarding the status of each DOM behaviour, that is, whether the presence or absence of a behaviour could be considered a failed or passed response. An exhaustive list of over 700 discrete oral motor behaviours was compiled, between 75-90 for each oral motor challenge category. The task of ensuring that each behaviour could be defined as normal or abnormal was complicated. As the literature review highlighted there was a paucity of research in the area. Whilst a large standardisation sample would be ideal in order to accurately describe abnormal verses normal oral motor function it was not possible within the constraints of this thesis.

A number of approaches were therefore considered. However none of these approaches could be adopted in isolation and a combination was used to establish a normal - abnormal classification for each behaviour. They included:

1. Theoretical approaches. That is, was knowledge of normal and abnormal development sufficient to be able to clearly define the status of each discrete behaviour?

Where possible, decisions were supported by references in the literature which defined normal and abnormal oral motor behaviour in infants aged 12-18 months. However, comprehensive data did not always exist and the data available, were

often confounded by numerous factors known to affect the development of oral motor skills in infancy.

2. The use of developmental norms was considered important.

Almost no developmental data were available. Developmental age, as in other areas of child development, was considered an important factor in the decision making process. For example, the absence of a particular behaviour in a child aged 6 months may not necessarily be considered a failed response, whereas absence of the same skill during the latter stages of infancy would be considered as a failed response. Young infants are often unable, for example, to use their upper and lower lips to clean the spoon and do not use rotary jaw movements when munching solid textures. However, by the later stages of infancy these DOM behaviours would be part of the infant's oral motor repertoire.

Similarly, texture was also an important factor; the absence of some DOM behaviours, such as lateral tongue and jaw movements for purée or semi-solids, would not be considered failed responses whereas their absence when dealing with a more challenging texture, such as the solids or crackers, would be considered as a failed response. There is evidence to suggest that normal children use the method requiring the least effort for dealing with food orally. They will for example, often ingest foods such as semi-solids by sucking or munching instead of using a more mature chewing pattern.

3. Clinical insight could be used to judge the significance of individual behaviours.

Few clinicians use standardised methods for recording and judging oral motor performance in their clinical practice. Furthermore few can reliably agree on distinctions regarding normal and abnormal behaviour. Where no data were available from previous studies, decisions were made on the basis of the rater's clinical experience in evaluating the oral motor skills of more than 100 normally developing children.

4. Statistical methods could be considered to make distinctions. between normal and abnormal behaviour.

A variety of statistical methods were considered. They included:

- Factor analysis
- Discriminant analysis and
- Cluster analysis

Factor analysis is normally used to identify a relatively small number of factors that represent relationships within or among sets of many interrelated variables. Factor analysis requires the identification of a set of 'not-easily-observable' or underlying factors based on a set of readily observable variables (NoruŠis 1990). The basic assumption in factor analysis is that these underlying factors can be used to explain more complex phenomena. In the current study the interest

initially was not in the relationships between or among variables but rather in a technique that would discriminate between relatively homogenous groups of cases. Furthermore, the SOMA resulted in a rather large number of variables which could not have been entered into a factor analysis without considerable data reduction. Therefore, factor analysis was not considered an appropriate method to adopt in order to prove/disprove the proposed hypotheses.

Discriminant analysis, which involves computing 'discriminant scores' for each individual case in order to predict group membership, was also considered. Discriminant scores are obtained by establishing linear combinations of the independent variables. However, a prerequisite of discriminant analysis is that there is prior knowledge of group membership for the cases used to derive the classification rules (Norusis 1990). Although the group membership of all the children in the sample was known, the status of their oral motor skills was not known.

Cluster analysis was the chosen method for analysis for 2 reasons:

- First, group membership for all 127 children included in the analysis was 'technically' unknown. That is, how the cases would be distributed in terms of normal/abnormal oral motor function was unknown.
- Second, by using cluster analysis it was possible to identify homogeneous groups or clusters of cases and to study the characteristics or behaviours shared by each cluster. Finally, how each cluster differed from each other could also be studied.

The procedures adopted will be discussed in greater detail in the second part of this chapter, which details the results of the development study. Full details of the steps undertaken in the analysis are described in Skuse et al (1995) and Reilly et al (1995) in appendix 1. Statistical analysis were undertaken using SPSS-PC, version 4.0.

Reliability

A vital stage in developing an instrument is that of determining how reliable it is. This is usually measured in two ways; first, the inter-rater reliability of the instrument and second, the test-retest reliability. Inter-rater reliability compares the ability of two independent observers to rate and classify subjects into two or more groups. Test-retest reliability compares test results taken on two separate occasions.

Inter-rater reliability

Two therapists independently rated the video tapes of 10 children. The tapes were randomly chosen by an independent research worker. Three trials for each child were rated resulting in a total of 30 possible ratings for comparison purposes. The aim was to ascertain the agreement between the two raters. The simplest measure often used to measure agreement is to simply ascertain how many agreements were observed or the percent agreement. The per cent agreement are shown in the final rows of table 1. However, there are a number of problems with this approach as it takes no account of where the agreements occurred and most importantly does not take into account the degree of

agreement that could be expected by chance.

In this thesis, the degree of agreement was measured using the kappa coefficient which considers the agreement in excess of the amount of agreement that could arise purely by chance. Kappa's were calculated for each individual discrete oral motor behaviour and the procedure repeated for each oral motor challenge category, involving a total of more than 700 behaviours.

When agreement is perfect the maximum of 1.0 is obtained, a value of zero indicates no agreement better than chance. Negative values show worse than chance agreement (Landis and Koch 1977).

The kappas were calculated on 2 levels:

- first, was there agreement as to whether the behaviour could be rated
- second, if the behaviour could be rated did the raters agree as to the presence or absence of the behaviour.

In the following table (table 1), an example of how the rateable verses non-rateable categories were calculated is given. As can be seen, all of the 23 behaviours displayed that relate to Lip2 (from the oral motor challenge category - purée) were rateable by both raters. That is, the behaviour lip2, could be rated as present or absent and given a score of '1' or '0'. However, the situation for tongue 10 (from the oral motor challenge category - purée) is different as only 25 of the behaviours were scored as rateable by both raters. That is, in the case

of five pairs of ratings (shaded items) there were either disagreements as to whether the item could be rated or not, or both raters agreed that the item could not be rated.

For lip 2 then, the kappa statistic could be computed on all 30 items. There was perfect agreement as to the rateable verses non - rateable status of this behaviour but 3 disagreements (shaded areas) in the ratings of the behaviour.

For the behaviour tongue 10, there were 5 disagreements as to the rateability of this behaviour and therefore only 25 behaviours were rateable for both observers. The kappa statistic was computed on this reduced number of 25 behaviours. As there were no disagreements the kappa was 1.0.

This procedure was carried out initially for each discrete oral motor behaviour in all 7 oral motor challenge categories. Full details of the inter-rater reliability results are reported in Reilly et al (1995) in appendix 1.

Table 1. Computation of kappa statistics.

Oral motor behaviour			
Lip 2		Tongue 10	
rater 1	rater 2	rater 1	rater 2
1	1	1	1
1	1	1	1
1	0	1	1
1	0	8 *	0
1	1	1	1
0	0	0	0
0	0	0	8
1	1	1	1
0	0	8	8
0	0	1	1
0	0	0	0
0	1	1	1
0	0	8	1
0	0	0	0
0	0	0	0
1	1	0	0
1	1	8	0
0	0	1	1
.....	.....	.....	.....
1	1	1	1
0	0	0	0
0	0	1	1
1	1	0	0
Rateable verses non-rateable			
perfect agreement		5 disagreements (83% agreement)	
Rateable behaviours			
3 disagreements (90% agreement)		perfect agreement	

* a score of '8' indicated that the behaviour could not be rated. Scores of '1' indicated presence and '0', absence of the behaviour.

Test - retest reliability was evaluated by comparing the consistency between two separate trials. That is, the ratings of the first and third trial (for the same 10 subjects used in the inter-rater reliability study) were compared, thus measuring the consistency between the two trials. The score sheets were chosen randomly by an independent researcher blind to case status. The same procedure was repeated. First, kappas were computed for each pair of ratings as to whether they were rateable or non-rateable. Second, kappas were computed for all rateable responses. The results are reported in full in Reilly et al (1995) in appendix 1.

Table 2 summarises the number and proportion of the kappa values computed for the DOM behaviours that fell into the categories defined by Landis and Koch (1977). Results are shown for both stage 1 and stage 2 kappa calculations for inter-rater reliabilities. In table 3, the number and proportions of the kappa values for the consistency ratings, that is comparing trial 1 and trial 3, are also shown giving the ranges as recommended by Landis and Koch (1977)

Table 2: Number and proportion of DOM behaviours that fell into each of the kappa ranges defined by Landis and Koch (1977). Results shown are for the inter-rater reliabilities.

Stage 1 - Rateability of each behaviour							
Kappa range*	**Purée**	**Semi-solids**	**Solids**	**Cracker**	**Bottle**	**Trainer-cup**	**Cup**
1.0	40 (64%)	41 (60%)	24 (36%)	47 (66%)	52 (93%)	48 (83%)	48 (83%)
> 0.75	9 (15%)	23 (34%)	28 (42%)	12 (16%)	4 (7%)	7 (12%)	6 (10%)
0.40 - 0.75	10 (16%)	3 (5%)	15 (22%)	11 (15%)	0	3 (5%)	1 (2%)
< 0.40	3 (5%)	1 (1%)	0	2 (3%)	0	0	3 (5%)
Stage 2 - Absence/presence of each behaviour							
1.0	29 (48%)	32 (49%)	40 (67%)	42 (61%)	42 (75%)	41 (75%)	37 (67%)
> 0.75	8 (13%)	4 (6%)	2 (3%)	4 (6%)	1 (2%)	1 (2%)	1 (2%)
0.40 - 0.75	19 (31%)	22 (33%)	16 (27%)	13 (19%)	13 (23%)	10 (18%)	15 (27%)
< 0.40	5 (8%)	8 (12%)	2 (3%)	10 (14%)	0	3 (5%)	2 (4%)

* Landis and Koch (1977)

Table 3: Number and proportion of DOM behaviours that fell into each of the kappa ranges defined by Landis and Koch (1977). Results shown are for the consistency ratings between trial 1 and trial 3.

Consistency ratings between trial 1 and trial 3							
Kappa range*	**Purée**	**Semi-solids**	**Solids**	**Cracker**	**Bottle**	**Trainer-cup**	**Cup**
1.0	50 (77%)	66 (97%)	44 (64%)	68 (91%)	38 (93%)	47 (81%)	50 (86%)
> 0.75	7 (11%)	1 (1.5%)	10 (14%)	1 (1%)	0	4 (7%)	4 (7%)
0.40 - 0.75	8 (12%)	1 (1.5%)	14 (20%)	4 (5%)	3 (7%)	7 (12%)	4 (7%)
<0.40	0	0	1 (2%)	2 (3%)	0	0	0

Part 2 - Results:

Introduction

The results of the development study are described in full in 3 papers submitted in appendix 1 (Reilly and Skuse 1992, Reilly et al 1995 and Skuse et al 1995).

Procedures

In order to establish the validity of the SOMA a number of steps were undertaken. Each will be described in turn and the relevant results presented. Only one OMC category - purée will be presented in detail and used to illustrate the procedures undertaken and the results obtained. The results of the other OMC categories will be presented in accompanying tables.

Step 1 - Establishing a pass/fail response. A pass/fail response was identified for each discrete oral motor

As discussed in part 1 of this chapter, decisions had to be made regarding the status of each DOM behaviour. In doing so, the status of each behaviour had to be considered individually for each OMC category. For example, the absence of lateral or rotary jaw movements for semi-solids would not be considered abnormal, as such textures can be ingested by munching and do not require such mature movements. However, the absence of such movements for solids or crackers would be considered abnormal.

The decisions were based on:

- the modal response for the comparison group
- clinical judgement
- expectations for children up to the age of 24 months using normative data wherever available.

As a result each DOM behaviour was re-coded so that a score of 1 represented a failed response and 0 as passed. Tables 3 to 10 in Reilly et al (1995) in appendix 1 show the status of each discrete oral motor behaviour as indicated in the column headed behavioural status.

Step 2. Procedures for dealing with missing data. Behaviours which could not be rated reliably, were not observed, or where there was a large proportion of missing data were excluded from the analysis.

A number of procedures for dealing with missing data were developed and are fully described in Reilly et al (1995) and Skuse et al (1995). The cluster analysis described earlier in this chapter required list-wise deletion of cases with missing data, so if a child had any missing data (even on one variable) they would be excluded from the analysis. Because there was a relatively large quantity of missing data, for a variety of reasons, it was important to prevent a drastic reduction in sample size through list wise deletion. The following procedures

were therefore adopted.

- First, it was necessary to identify any DOM not observed in a number of children. These individual behaviours were not rated with sufficient frequency to warrant their inclusion in further analysis of skills associated with that OMC category. They were therefore excluded altogether. The procedure was carried out separately for each OMC category because the amount of missing data varied across categories.

- Second, where there were missing data, other trials were substituted if necessary. As described earlier, three examiner administered trials of each oral motor challenge category and one self feeding trial were rated. Initially, the data from trial 1 and 3 were included in the data analysis. However, other trials were available and substituted. For example, if trial 1 or 3 were missing then trial 2 or 4 could be substituted. A further procedure involved substituting missing data with data from alternate trials. For example, if subsets of data were missing from trial 1 or 3, then trial 2 or trial 4 data were substituted. This procedure was only applied after ascertaining that the trial data were the same and there was consistency of performance across trials.

- Third, any items that could not be rated with adequate inter-rater reliability were excluded from the analysis.

- Finally, the majority of missing data for the CP subjects were accounted for by their failure to cope with the feeding task. For example, they were unable to take the food into their mouths, or keep the food within the mouth because of the severity of their oral motor or postural problems. In the case of some severely impaired children it was not considered 'safe' to feed particular solid textures because of the risk of aspiration of solid foodstuffs. For these reasons, where data were not available for any of the subjects with CP, as a result of them being unable to cope with the challenge presented, the trial was coded as 'failed'.

Through the joint use of the procedures developed for reducing missing data it was possible to maintain the sample size (n=127).

Step 3 - Discrete oral motor behaviours entering the analysis. Decisions were made as to which DOM would enter the analysis

A list of the DOM behaviours included in the final analysis for each OMC category can be found in table 4. An explanation for each of the DOM behaviours shown can be found in tables 3 to 10 in Reilly et al (1995) in appendix 1.

Table 4. Oral-motor behaviours entering analysis for each OMC category.

	Purée	Semi-solids	Solids	Cracker	Bottle	Trainer cup	Cup
react 1							
react 2							
react 3							
react 4							
react 5							
accept 1		*		*	*	*	*
accept 2	*						
foodloss1							
foodloss2	*	*	*	*			
drool 1					*	*	*
drool 2			*		*	*	*
sequence1						*	
sequence2				*			
sequence3				*			
initiation1					*	*	*
initiation2	*	*	*	*			
initiation3					*		*
initiation4					*		*
lip1					*	*	*
lip2					*	*	*
lip3							
lip4							
lip5	*	*	*	*			
lip6	*	*	*	*			
lip7							
lip8							
lip9							
lip10							

lip11							
lip12							
lip13	*		*	*			
tongue1	*	*	*	*	*	*	*
tongue2	*	*	*	*	*	*	*
tongue3	*	*	*	*	*	*	*
tongue4	*	*	*	*	*	*	*
tongue5	*	*	*	*	*	*	*
tongue6		*	*	*			
tongue7		*	*	*			
tongue8		*	*	*			
tongue9		*	*	*			
tongue10							
tongue11							
tongue12							
tongue13							
tongue14			*	*			
tongue15			*	*			
jaw1							
jaw2							
jaw3					*	*	*
jaw4						*	
jaw5					*		*
jaw6					*		*
jaw7					*		*
jaw8					*		*
jaw9					*		*
jaw10				*	*		*
jaw11					*		*
jaw12					*		*
jaw13	*						
swallow1	*	*	*	*	*		*
swallow2	*	*	*	*	*		*

swallow3	*	*	*	*	*	*	*
swallow4	*	*	*	*	*		*
swallow5	*	*	*	*	*		*
swallow6	*	*	*	*	*		*
swallow7	*	*	*	*	*		*
swallow8		*		*	*	*	*
swallow9		*				*	
swallow10		*		*			
swallow11		*		*		*	
swallow12				*	*		*
bite1							
bite2							
bite3							
bite4							
bite5							
bite6							
bite7							
bite8							
bite9							
bite10							
bite11							
bite12							

shading indicates that the oral motor behaviour was entered into the analysis for that foodstuff

* indicates that the DOM behaviour was not entered into the analysis for that foodstuff either because it had poor reliability or was not rateable.

blank boxes indicate that the DOM behaviour was not applicable to the OMC category

Step 4. Analysis. Cluster analysis, a well established technique for identifying patterns or profiles of behaviours, was chosen as the method of analysis and applied to the sample. The cases where there was known pathology, that is, the children with cerebral palsy, acted as 'seeds'. The term 'seeded cluster analysis' was adopted to describe the procedure undertaken.

The procedure known as 'agglomerative hierarchical clustering' because of its step by step procedure, was used. The clusters are formed by grouping cases into bigger and bigger clusters until all cases are members of a single cluster (Everitt 1974). The process begins with each child being considered as though he/she is completely separate and unique cluster, that is, there are as many clusters as subjects (n=127). The subjects are then progressively allocated to larger and larger groups as the clustering progresses. Eventually all the subjects are in one large single cluster.

With a sample size of 127, there are 127 sequential steps to the procedure as just 2 children or clusters are merged at each step. Ward's method which identifies which children and clusters are closest to one another and then groups them in increasingly larger conglomerates at each step in the analysis, was used (Everitt 1974). In cluster analysis the distance, (ie: how far apart 2 cases or behaviours are) and the similarity, (ie: closeness) are important. Similarity measures are large for cases that are similar and distance measures are small. Cases are therefore grouped on the basis of their 'nearness'. The squared Euclidean distance (the sum of the squared differences over all the variables) between children was used as the dissimilarity metric.

It is possible to get a visual representation of the steps in the analysis called a dendrogram which displays the clusters being combined and the values of the coefficients at each step. After inspection of the dendrograms, a decision was made to select a 5 cluster solution as the basis for further analysis. The best cluster solution was one which took into account the cluster sizes in successive groupings, the similarity and distance measures and later, the distribution of children with cerebral palsy across clusters.

Step 5. Cluster analysis - results. The proportion of children in each cluster who failed on each discrete oral motor skill were summarised and tabulated. This procedure was repeated for each OMC category.

The data in table 5 show a sample of just some of the 45 DOM behaviours entered into the analysis for the OMC category purée. The figures shown are representative of the proportion of children within each cluster who 'failed' each DOM behaviour. For example, sequence 3 refers to whether or not the child was observed to choke, cough or gag whilst being fed purée. A failed response meant the behaviour was observed. None of the children in cluster A, cluster B or cluster C choked, coughed or gagged and therefore did not fail on that particular DOM behaviour. However, three per cent of children in cluster D did and the majority of children in cluster E (88%) coughed, choked or gagged and therefore failed sequence 3.

Table 5 Preliminary 5 cluster solution for purée: Proportion* of children in each OMC category who 'failed' the oral motor skill

	Cluster A (n=27)	Cluster B (n=24)	Cluster C (n=34)	Cluster D (n=35)	Cluster E (n=7)
React1	4	0	12	**37**	**72**
React2	0	0	3	23	0
React3	4	0	0	11	29
React4	0	0	3	0	14
React5	0	4	0	0	14
Accept1	11	0	12	23	**86**
Accept2	4	0	9	9	**57**
FoodLoss1	7	0	9	17	**71**
Foodloss2	0	0	3	0	0
Drool1	0	0	9	**43**	**100**
Drool2	0	0	0	3	**43**
Sequence1	0	0	0	0	29
Sequence2	**44**	0	22	20	**57**
Sequence3	0	0	0	3	**88**
Init1	7	**100**	3	0	**88**
....	....	....	....	....	....
Bite12	0	1	0	0	29

* percentage of children within each cluster who failed each DOM behaviour shown

Clearly some cut off point was necessary. The behaviour 'accept 1' refers to whether the child was able to accept the food within 2 seconds of it being offered. Apart from cluster B , where no cluster members failed the item, a proportion of members from all other clusters failed this behaviour. However, as can be seen the proportions varied considerably from 11% in cluster A, to 23% in cluster D and 86% in cluster E. At this stage in the analysis all items where at least 30%

of the children in a cluster had failed the DOM behaviour in question were highlighted. This cut off point distinguished, in most cases, just 1 or 2 clusters which contained a high proportion of cluster members (usually many more than 30%) who failed the DOM skill in question. In table 5 the behaviours that were failed by 30% or more of the members of that cluster are shown by the shaded boxes.

Step 6. Identification of normal and abnormal clusters on the basis of the number of DOM behaviours failed by the cluster members.

Table 6 summarises just 3 of the OMC categories - (purée, solids and cracker). The figures presented in the table are the proportions of DOM behaviours that entered the cluster analysis which were failed by 30% or more of the cluster members. Cluster E (OMC category - cracker) was designated an abnormal cluster because 94% of the DOM behaviours (45/48) entering the analysis were failed by at least 30% of the members of the cluster. Similarly, 35 of the 48 DOM behaviours (73%) were failed in cluster C. The same can be said for cluster D - solids and cluster E - purée, and so on.

The abnormal clusters have been highlighted by shading and are in stark contrast to the remaining clusters where very few of the behaviours were failed. Take for example, cluster B in the OMC category- purée. Only 1 (2%) of the

DOM behaviours was failed. Similarly in both cluster A and C, 4 DOM behaviours (9%) were failed.

Table 6 The relationship between OMC categories, DOM skills and cluster designation

OMC category	Total * behaviours	Cluster A	Cluster B	Cluster C	Cluster D	Cluster E
Purée	45	4 (9%)	1 (2%)	4 (9%)	14 (31%)	25 (55%)
Solids	44	4 (9%)	1 (2%)	15 (34%)	39 (89%)	3 (7%)
Cracker	48	4 (8%)	1(2%)	35 (73%)	8 (18%)	45 (94%)

* total number of behaviours entering the analysis for each OMC category

The procedure as outlined in steps 4 and 5 was repeated for each OMC category and the results tabulated in the same manner.

Step 7. Cluster ranking. Each of the five clusters were then ranked according to the degree of abnormality. Those clusters containing a large number of failed DOM behaviours were designated abnormal and those with a few or a minority of failed DOM, were designated 'normal'. Clusters were now ranked in order of the number of DOM behaviours failed.

The ranking of the abnormality status of each cluster was based therefore on the proportion of behaviours failed by the members of each cluster. For example, a ranking of 5 would indicate the most abnormal cluster, or the cluster where the

highest proportion of members failed the behaviours and 1 the most normal cluster or where the least number of behaviours were failed.

Clearly for OMC category - purée, clusters D and E were the most abnormal whereas clusters A, B and C were designated as normal (see table 6 for proportion of behaviours failed and table 7 for cluster rankings). Up to this point the procedure was not concerned with the actual status of the cluster members. For the majority of OMC categories (purée, semi-solids, solids, cracker and cup), 2 clusters were clearly identified as being abnormal, the remaining 3 clusters were then designated as normal. However, this was not the case for bottle where 3 clusters contained a high proportion of members who failed many DOM behaviours and therefore could be identified as abnormal. However, one of these clusters (cluster E) contained only 3 cluster members (see table 8 in Skuse et al (1995) in appendix 1). A different solution was found for trainer - cup where only one cluster was clearly identified as abnormal (cluster A) which can be seen in table 9 in Skuse et al (1995) in appendix 1.

Step 8. Establishing the status of cluster membership. Case status was crosstabulated by cluster designation.

The results of the crosstabulation of cluster membership by cluster designation are shown in table 5 along with the cluster rankings for the OMC category purée and cluster membership. Details regarding the rankings for the other OMC categories can be found in Skuse et al (1995) in appendix 1. The 2 clusters (cluster D and E)

designated as abnormal each contained 46% of the children with CP. No comparison subjects belonged to the most abnormal cluster (E) and only 5 (9%) occurred in cluster D. Similarly only 1 subject (2%) with NOFT occurred in the most abnormal cluster whilst 24 (43%) occurred in cluster D.

Table 7. Cluster rankings OMC category - purée.

Cluster	Descriptor	Rank	NOFT	Comparison	CP
A	Normal	3	5 (9%)	21 (36%)	1 (8%)
B	Normal	1	12 (21%)	12 (21%)	0
C	Normal	2	14 (25%)	20 (34%)	0
D	Abnormal	4	24 (43%)	5 (9%)	6 (46%)
E	Abnormal	5	1 (2%)	0	6 (46%)

For the purposes of further analysis the clusters were amalgamated to produce 1 large abnormal cluster (the 2 abnormal clusters were merged) and a normal cluster (the 3 normal clusters were merged).

Step 9. The development of a screening procedure.

The final stage in the development study was to test the feasibility of developing a screening procedure which could determine with confidence whether a child's oral motor skills were deficient or not. The first step in developing the screen was to determine which behaviours were most discriminating and to include these in the development of the screening version. Table 8 shows the proportions of cluster members who failed a subset of DOM behaviours for the OMC-category purée. In total there were 45 DOM behaviours that entered the cluster analysis. However, a restricted subset of 26 behaviours is shown in table 8, these being

the behaviours that were failed by more than 30% of the cluster members of at least one cluster.

By studying clusters D and E (the 2 abnormal clusters) it is possible to distinguish a small group of behaviours that discriminate these 2 clusters from all other clusters. These behaviours are indicated by the shaded cells in table 6. The numbers in bold represent any DOM behaviour failed in any cluster.

Table 8. Cluster membership showing proportions (%) of members of individual clusters failing a subset of discrete oral motor skills (Purée)

	Abnormal clusters		Normal clusters		
	Cluster E	Cluster D	Cluster C	Cluster B	Cluster A
React 1	**72**	**37**	12	0	4
Accept 1	**86**	23	12	0	11
F.loss	**57**	9	9	0	4
Seq 1	**100**	**43**	9	0	0
Seq 2	**43**	3	0	0	0
Init 1	**57**	20	22	0	**44**
Init 3	**88**	3	0	0	0
Init 4	**86**	0	3	**100**	7
Lip 1	**86**	**91**	12	1	11
Lip 2	**86**	**83**	21	1	7
Lip 3	**100**	**100**	29	1	29
Lip 4	14	**40**	15	1	0
Lip 8	**100**	**77**	**91**	1	0
Lip 9	**100**	**34**	9	1	**100**
Lip 10	**100**	**86**	**50**	1	19
Lip 11	**100**	**71**	6	1	11
Lip 12	**100**	**94**	**74**	1	**63**
Tongue 10	**86**	6	**41**	1	0
Tongue 11	**30**	**46**	6	1	0
Tongue 12	**86**	**31**	24	1	0
Jaw 1	**86**	**46**	15	1	15
Jaw 2	**86**	17	0	1	0
Jaw 3	**86**	9	0	1	0
Jaw 9	**86**	3	3	1	7
Jaw 10	**71**	9	0	1	4
Jaw 11	**43**	3	0	1	0
Jaw 12	**43**	3	0	1	0

If the cut-off of 30% or more cluster members failing a particular DOM behaviour is taken, then there were 9 behaviours that were failed by members of cluster D and E but not by the remaining clusters. This list of behaviours (shown in the shaded cells in table 8) could then be said to distinguish the abnormal (clusters D and E) from the normal clusters (A, B and C). Explanations of each of these behaviours can be found in table 12. The behaviours are:

- **React 1**
- **Sequence 1**
- **Lip 1**
- **Lip 2**
- **Lip 3**
- **Lip 11**
- **Tongue 11**
- **Tongue 12**
- **Jaw 1**

These 9 behaviours were failed by more than 30% of the members of the 2 abnormal clusters in the oral motor challenge category purée, but passed by all the members of the normal clusters. A provisional abnormality score was devised based on this subset of 9 discrete oral motor behaviours. In the development study this was termed the 'total dysfunction score' (Skuse et al 1995). A high score would indicate greater abnormality and membership of an abnormal cluster, whereas a low score, membership of a normal cluster. Cut off points for each oral

motor challenge category were devised. A score above the cut off point would predict membership of an abnormal cluster and below the cut off point, membership of a normal cluster. This procedure was repeated for each OMC category.

In the OMC categories where there were not 2 clearly abnormal clusters (bottle and trainer cup) other procedures were adopted. For bottle, three abnormal clusters were identified, although one of these (cluster E) contained very few cluster members. It seemed logical therefore to use the behaviours that discriminated these three clusters from the two normal clusters to produce the index. In the case of trainer-cup where only one cluster was clearly abnormal, the behaviours that discriminated this cluster from all others was used to generate the index.

Full results for each of the OMC categories are reported in Skuse et al (1995) in appendix 1.

Table 9 shows the relationship between the total dysfunction scores obtained by individual children and cluster membership for the OMC-category - purée. Clearly some decision regarding an ideal cut off point was necessary. In examining table 9 there appears to be a natural cutting point at 2 which separates the normal and abnormal amalgamated clusters.

Table 9. **Purée**: The relationship between the total dysfunction scores obtained by individual children and cluster membership.

Total dysfunction scores	Abnormal clusters	Normal clusters
0	0	46
1	0	19
2	1	16
3	2	1
4	7	3
5	8	0
6	9	0
7	7	0
8	7	0
9	1	0

However, in order to test the efficiency of this reduced index of behaviours as a screening procedure it was important to see how well it predicted group membership. To do so it was necessary to calculate;

- the sensitivity of the screening instrument, that is, the proportion of true cases or true positive rate
- the positive predictive value - the probability that a screen-positive is truly a case and
- the specificity of the instrument - or the true negative rate.

In figure 2 examples are given of how the sensitivity, specificity and positive predictive values were calculated. There are 41 true positives (cell a). These are subjects who scored above the threshold and belonged to the groups designated

as abnormal (that is, abnormal clusters). In cell b there are 4 false positives, that is children who scored above the threshold but belonged to a group designated as normal. Cell c contains only 1 child who scored below the threshold but belonged to a group designated as abnormal, that is, a false negative. Finally, cell d contains 81 subjects or true negatives. These children scored below the threshold and belonged to normal groups, that is normal clusters. In table 11 details of the efficiency of the screening procedure in predicting group membership are given for just one OMC category purée. Skuse et al (1995) in appendix 1 gives full details of the calculations for each OMC category.

Figure 2. Calculation of sensitivity, positive predictive value and specificity for sample 1.

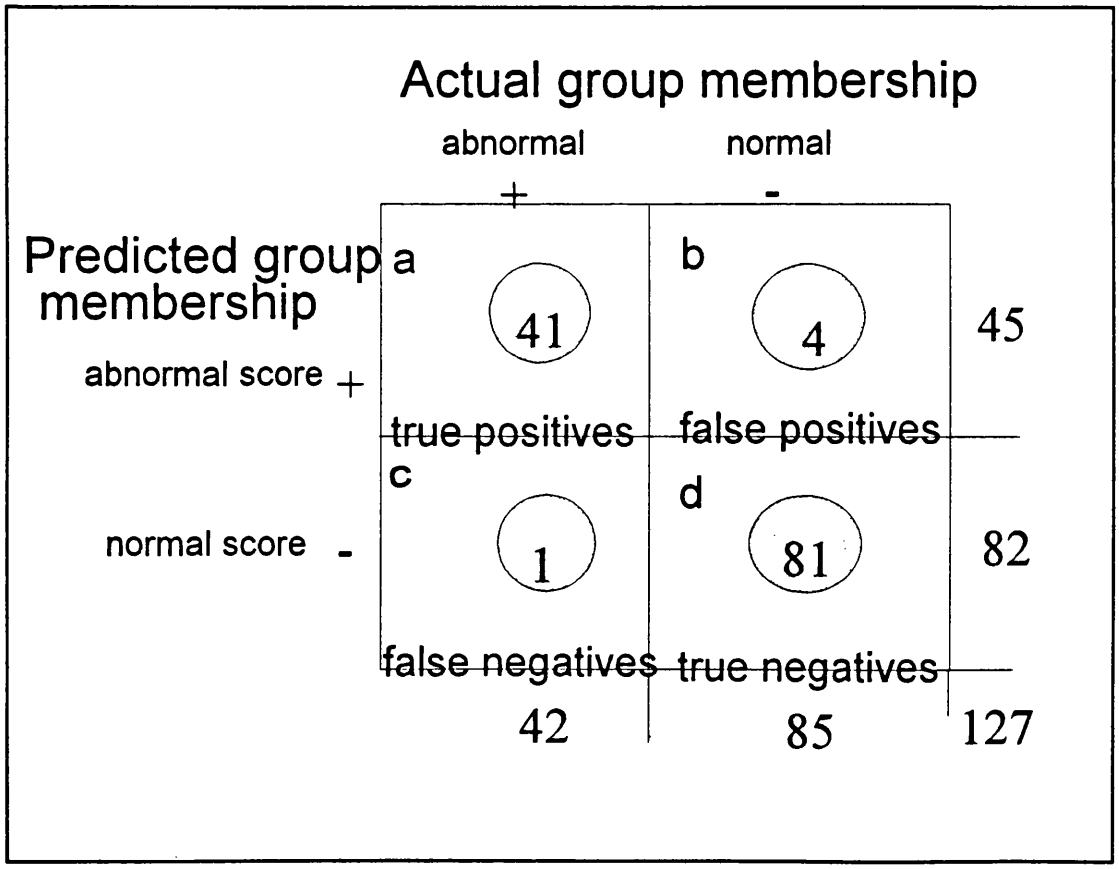


Table 10. **Purée:** Positive predictive value, sensitivity and specificity calculations.

Predicted group	Abnormal	Normal	PPV	Sensitivity	Specificity
Abnormal	41	4	98	91	.95
Normal	1	81			

The screening index and cutting points for each OMC category are shown in tables 11 to 17. The shaded cells indicate the abnormal responses and are totalled to provide the abnormality or total dysfunction score.

Table 11 : SOMA Screening version for **Purée**

Purée		yes	no
react 1	head orientation to spoon	y	n
sequence 1	smooth rhythmic sequence	y	n
lip 1	lower lip draws inwards around spoon	y	n
lip 2	upper lip removes food from spoon	y	n
lip 3	lower/upper lip assist in cleaning	y	n
lip 11	lower lip active during suck/munch/chew	y	n
tongue 11	consistent/considerable protrusion	y	n
tongue 12	protrusion beyond incisors	y	n
jaw 1	graded jaw opening	y	n
cutting score of 3 or more			

The 9 DOM behaviours shown in table 11 represent the screening index for the OMC category, purée. Either the box shaded 'yes' or that shaded 'no' are checked for each subject being assessed. The shaded boxes indicate the

abnormal responses for each behaviour. Shaded boxes are totalled to provide an abnormality score. Scores below the threshold (2 or less) indicate normal oral motor performance for purée whereas scores above 2 indicate the presence of oral motor dysfunction.

Table 12 : SOMA Screening version for **semi-solids**

Semi-solids		yes	no
drool 1	consistent/considerable drooling	y	n
sequence 1	smooth rhythmic sequence	y	n
initiation 1	sequence initiated within 2 seconds	y	n
lip 13	lips closed during swallow	y	n
jaw 1	graded jaw opening	y	n
jaw 2	internal jaw stabilisation	y	n
jaw 3	external jaw stabilisation required 100%	y	n
jaw 10	associated jaw movements	y	n
cutting score 4 or more			

There were 8 DOM behaviours which formed the screening index for semi-solids. The cut-off score was 4, children scoring above 4 having abnormal oral motor skills and those scoring 3 or below, normal oral motor functioning.

Table 13: SOMA screening version for **solids**

Solids		yes	no
food loss 1	less than 25% of food lost	y	n
drool 1	profuse/marked drooling	y	
sequence 1	smooth rhythmic sequence	y	n
lip 1	lower lip draws inwards around spoon	y	n
lip 2	upper lip removes food from spoon	y	n
lip 4	lower lip behind upper teeth/sucking	y	n
lip 11	lower lip active during suck/munch/chew	y	n
tongue 10	transient minimal tongue protrusion	y	n
jaw 1	graded jaw opening	y	n
cutting score 4 or more			

Nine DOM behaviours made up the screening index for the OMC category solids. The cut-off score was 4; scores of 4 or more indicate that there is oral motor dysfunction and scores below the threshold, normal oral motor function.

$\checkmark (< 4)$

Table 14. SOMA screening version for **Cracker**

Cracker		yes	no
food loss 1	profuse/marked food loss	y	
Drool 1	profuse/marked drooling	y	
initiation 1	sequence initiated within 2 seconds	y	n
lip 4	lower lip behind upper teeth to suck	y	n
lip 7	lips close around stimulus during bite	y	n
lip 9	lips close intermittently during suck/munch/chew	y	n
tongue 10	transient minimal tongue protrusion	y	n
tongue 11	considerable/consistent tongue protrusion	y	n
tongue 12	protrusion beyond incisors	y	n
tongue 13	protrusion beyond lips	y	n
jaw 2	internal jaw stabilisation established	y	n
jaw 3	variable stabilisation (not fully established)	y	
jaw 4	external stabilisation required	y	n
jaw 5	vertical movements	y	n
jaw 8	wide vertical excursions	y	n
jaw 9	small vertical excursions	y	n
jaw 11	associated head movements to bite	y	n
jaw 12	uses fingers to transfer food	y	n
swallow 9	gagging	y	n
bite 5	controlled sustained bite	y	n
bite 8	graded jaw opening	y	n
bite 12	mouths cracker only	y	n
cutting score 9 or more			

Twenty-two DOM behaviours made up the screening version for the OMC category cracker. A cutting score of 9 or more was used to separate subjects with normal

from those with abnormal oral motor function. A score above the threshold (9 or more) was indicative of oral motor dysfunction.

Table 15 : SOMA screening version for **bottle**

Bottle		yes	no
react2	anticipatory mouth opening	y	n
react 4	no liquid enters mouth	y	n
accept 2	accepts liquid within 2 seconds	y	n
lip 3	upper lip firmly seals around teat	y	n
lip 5	intermittent/incomplete upper lip contact/seal	y	n
lip 6	intermittent/incomplete upper lip contact/seal	y	n
lip 7	lip closure during swallow	y	n
jaw 1	small vertical movements	y	n
sequence 1	smooth rhythmic sequence	y	n
cutting score 5 or more			

Nine behaviours formed the screening index for the OMC category bottle. A cutting score of 5 or more was used. Scores above the threshold (5 or more) were indicative of oral motor dysfunction.

Table 16: SOMA screening version for trainer cup

Trainer cup		**yes**	**no**
liquid loss	profuse/marked liquid loss	y	n
sequencing 2	panic reactions when liquid presented	y	n
sequencing 3	choking	y	n
tongue 10	tongue thrust	y	n
tongue 11	asymmetry	y	n
jaw 1	small vertical movements	y	n
jaw 6	jaw alignment during drinking	y	n
jaw 10	external jaw stabilisation 100%	y	n
jaw 12	internal stabilisation	y	n
swallow 1	jaw alignment	y	n
swallow 4	panic reactions during/after swallow	y	n
swallow 5	no swallow observed	y	n
swallow 6	uses gravity eg: head extension	y	n
swallow 7	numerous attempts to initiate swallow	y	
cutting score of 5 or more			

Fifteen DOM behaviours formed the screening index for the OMC category - trainer cup. Scores above the threshold (5 or more) indicated the presence of oral motor dysfunction, whereas scores below 5 indicated normal oral motor functioning.

Table 17 : SOMA screening version for cup

Cup		yes	no
accept 2	accepts within 2 seconds	y	n
sequencing 2	panic reactions when liquid placed in mouth	y	n
sequencing 3	choking	y	
liquid loss	profuse/marked liquid loss	y	
tongue 10	tongue thrust	y	n
tongue 11	asymmetry	y	n
jaw 1	small vertical movements	y	n
jaw 4	jaw clenching	y	n
swallow 9	gagging	y	n
cutting score 5 or more			

Nine behaviours formed the screening index for the OMC category - cup. A cutting score of 5 or more was used, scores above the threshold indicated the presence of oral motor dysfunction whereas those below the threshold, indicated normal oral motor function.

Chapter 5 The Validation Study - methodology and results

Methodology

Introduction

The development study demonstrated that the SOMA was a sensitive instrument capable of identifying children with grossly abnormal oral motor skills. However, the screening procedure was evaluated on the same sample of children from which the original groups were identified. Applying the instrument therefore to an independent sample of children would further validate the findings of the development study by establishing:

- First, if the SOMA would accurately differentiate between groups of children with and without oral motor dysfunction.
- Second, if the screening version of the SOMA would provide as good discrimination between the designated normal and normal groups.
- Third, if the positive predictive values and sensitivity of the instrument would be as good.

This chapter is divided into 2 parts.

- Part 1, describes briefly the methodology adopted which in many aspects is identical to the development study.
- Part 2, describes the results of the validation study and compares them to those obtained in the development study
- Part 3, describes further development and application of the screening instrument.

Study design and description of samples

Identification of subjects

NOFT and Comparison infants

The NOFT and comparison children were originally recruited to serve as a normative sample even though it was suspected that a minority of children with NOFT would have some oral motor dysfunction. The same 56 infants with NOFT and 58 comparison infants were used to establish the validity of the instrument. Details of the sample are given in chapter 4 and in Reilly et al (1995), Skuse et al (1995) and Reilly and Skuse (1992) in appendix 1. The SOMA data collected on these subjects was entered into the validation study.

Subjects with Cerebral Palsy

To fulfil the aims of the validation study therefore it was necessary to recruit an independent sample of children with cerebral palsy who would again act as 'seeds'. A further 13 children with cerebral palsy, closely resembling those from sample one (the development study) were identified and recruited. They were selected from a larger sample of children recruited in a community survey aiming to establish the prevalence, aetiology and management of feeding problems in preschool children with cerebral palsy (Reilly et al 1995). Two health districts took part in the survey, Southwark and North Lewisham and The City and Hackney.

Children were included in the study if they had;

- a confirmed diagnosis of cerebral palsy and
- were aged less than 60 months.

From the 50 children recruited to the community study, 13 were chosen to act as the second sample of children with cerebral palsy (Validation sample). The inclusion criteria for this sub-sample were identical to those used for sample one.

They included:

- a confirmed diagnosis of cerebral palsy
- age less than 60 months
- nominated by the paediatrician to have a significant degree of oral motor dysfunction
- nominated by their carer(s) to have a major feeding problem.

The children were matched as closely as possible to sample one (CP1) on a number of different variables which included:

- developmental age
- diagnosis (both type and distribution of the motor disorder and severity).
- sex

Whilst the aim was not to achieve a matched sample of children for comparison purposes, it was necessary to ensure that the sample closely resembled those children in sample one in terms of the severity of their oral motor dysfunction and factors which might affect it (see table 1). Figure 1 illustrates the composition of both sample one and sample two. Sample one was fully described in chapter 4 and included the children with NOFT and the comparisons and the first sample of children with cerebral palsy (CP1).

Sample two was made up of the same children with NOFT and the comparisons and a new sample of children with cerebral palsy (CP2) as is illustrated.

Figure 1. Sample characteristics

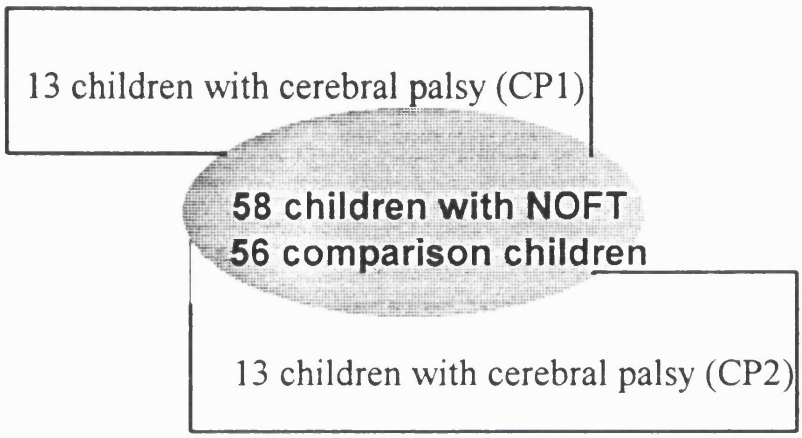


Table 1 shows the characteristics of both samples of children with cerebral, palsy. Chronological age, developmental age, diagnosis and additional deficits are given.

Table 1: The characteristics of CP1 and CP2 showing the diagnosis, age, developmental age and additional neurological deficits that coexisted with the cerebral palsy.

No.	Sex	Age (months)		Cognitive level* (mths)		Diagnosis **		Additional deficits	
		CP1	CP2	CP1	CP2	CP1	CP2	CP1	CP2
1	male	16	60	4	4	spastic quadriplegia	spastic quadriplegia	partial vision	? vision epilepsy
2	female	23	36	11.5	13	dystonic quadriplegia	dystonic quadriplegia	squint	squint
3	male	16	24	17	24	dystonic quadriplegia	dystonic quadriplegia	squint/ mild high frequency hearing loss	-
4	male	18	48	4	4	spastic quadriplegia	spastic quadriplegia	epilepsy hearing loss	epilepsy
5	male	17	48	3	< 4	spastic quadriplegia	spastic quadriplegia	severe hearing loss visual defect	epilepsy blind
6	male	19	22	10	13	spastic quadriplegia	spastic quadriplegia	epilepsy	
7	male	16	60	6	6	spastic quadriplegia	spastic quadriplegia	squint	epilepsy blind
8	female	26	60	6	6	spastic quadriplegia	spastic quadriplegia	blind epilepsy	epilepsy visual impairment
9	male	39	30	3	<4	spastic quadriplegia	spastic quadriplegia	partial vision	epilepsy partial vision
10	female	16	31	<3	<4	spastic quadriplegia	spastic quadriplegia	_	epilepsy / blind severe hearing loss
11	female	16	61	<3	<6	spastic quadriplegia	spastic quadriplegia	_	epilepsy hearing loss ? vision

12	male	15	38	9.5	9-12	spastic quadriplegia	spastic quadriplegia	–	blind epilepsy
13	male	18	40	<3	<4	spastic quadriplegia	spastic quadriplegia	–	epilepsy blind

* cognitive levels were measured using the Griffiths scale (Griffiths 1970) in the development study. For sample two a combination of the developmental assessments was used. From 4 to 10 months developmental age equivalent, 8 criterion behaviours were chosen, which required a minimum of physical coordination for their accomplishment. From 9 to 15 months (developmental age equivalent) the verbal comprehension scale of the Reynell-Zinkin scales for visually handicapped children (Reynell 1979) was used, within which children could respond to items by gross physical movement or by eye pointing. From 15 months age equivalent onwards, the Reynell Developmental Language Scales, Verbal Comprehension (Scale B - eye pointing) was used.

** diagnosis was made on the basis of the predominant type of motor disorder, for example, spastic versus dystonic and the distribution, for example quadriplegia or hemiplegia, using the Oxford Standard Recording of central Motor Deficit (Johnson et al 1989).

Recruitment

The advice of the community paediatricians and health professionals who were in regular contact with the families was sought. They referred the families to the study having had preliminary discussions regarding what was entailed. At the same time they sought the family's verbal permission to pass on their names and addresses.

Prior to commencing the study each district estimated that there were approximately 40 children in the district that met the inclusion criteria. An information pack was sent to each family. This contained a leaflet describing the study and a reply paid postcard on which the families could indicate whether they wished to take part. Once the family returned the postcard they were contacted by phone or letter to make an initial appointment for a home visit. The families received visits from two researchers. The first visit concentrated on the child's feeding. The second, carried out by the paediatrician, focused on the child's general health, and development, growth, neurological status and also included interviews with the parents about disclosure of the diagnosis and developmental history.

Procedure

For the purposes of the validation study the SOMA was the main instrument. The procedures used were identical to those described earlier in this chapter. For example, the visits were conducted in an identical manner, the SOMA was administered and scored using the same methodology already outlined

in chapter 4.

Data analysis

Statistical procedures/analysis

All statistical analysis was carried out using SPSS-PC version 4.0. The data for sample two were entered into ASCII files which were merged with the existing ASCII files for sample one. The files were then read into SPSS-PC version 4.0 which contained the steering files established for the development study. Full details of the methodology and the statistical procedures undertaken are explained in the development study and contained in Reilly et al (1995) and Skuse et al (1995) in appendix 1.

Analysis plan

A number of steps, as described in detail in the development study, were undertaken. They are summarised in table 2.

Procedures

The data from CP2 was entered and merged with the data obtained on the NOFT and comparison children. The methodology outlined in the Development study was repeated and each of the above data steps replicated. The same set of DOM behaviours was entered into the analysis for both data sets. A number of aspects of the validation study were of interest; for example, were the same behaviours common to both screening versions of the SOMA even though they were developed on two

independent samples. Although this was not crucial it would be excellent if many of the variables were common to both index 1 (sample 1) and index 2 (sample 2). Of greater interest was to ascertain if the index provided as good discrimination between the abnormal and normal diagnostic categories.

Table 2: Summary of the analysis steps undertaken in the development study.

1. The proportions of children, their cluster membership and diagnostic categories were summarised for each oral motor challenge category.
2. Cluster membership was crosstabulated by diagnostic category.
3. The variables that discriminated the abnormal from the normal clusters were summarised.
4. These variables were used to create a second screening version of the SOMA for sample 2.
5. The effectiveness of the index (sample 2), that is how well it discriminated between normal and abnormal group membership, was ascertained by calculating the sensitivity, specificity and positive predictive values .
6. The discrete oral motor behaviours that form index 1 (sample 1) and index 2 (sample 2) were compared.
7. The effectiveness of index 1 (sample 1) and index 2 (sample 2) were compared.
8. The effectiveness of a combined screening index (established by combining the index from sample one with that from sample two) will be tested.

Results:

Introduction

The steps as outlined in chapter 4 (Results, Procedures) will be reported for both the development and validation studies. For ease of presentation only the results from the OMC-category purée will be explained in detail. The remaining categories will be summarised in table form.

Cluster analysis - results

Identifying failed behaviours

The DOM behaviours entered into the analysis for OMC category 'purée' and the 5 cluster solution are shown in Table 3. Oral motor behaviours which were failed by 30% or more of the cluster members are displayed in bold. Data are shown for both sample one and sample two. The same methodology as outlined in the development study was adopted for identifying 'failed' behaviours, that is, behaviours failed by 30% or more of the members of the cluster. Consider, the oral motor behaviour, react 1 (head orientation towards the spoon) in table 3. First, study sample one; react 1, was failed by more than 30% of children belonging to cluster D and E, however, only 4% of subjects in cluster A, none in cluster B and 12% in cluster C, failed this behaviour. Second, study sample two; react 1, was failed by more than 30% of children in cluster A and B, whereas only 3% of cluster C, none in cluster D and 15% of cluster E failed the behaviour. The rationale behind decisions about what constituted 'failed items' were fully explained in the development study.

Table 3. Cluster membership showing proportions (%) of members of individual clusters failing a subset of discrete oral motor behaviours (shown in bold for the abnormal clusters) for the oral motor challenge category - purée. The results shown are for both sample one and 2. Shading indicates the abnormal clusters for each sample - the darkest shading shows the most abnormal cluster.

	Sample one					Sample two				
Behaviour	**Cluster numbers**					**Cluster numbers**				
	A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
react1	**4**	0	12	**37**	**71**	**78**	**35**	3	0	15
react2	0	0	3	23	0	**89**	18	0	0	4
react3	4	0	0	11	29	**78**	18	0	0	0
react4	0	0	3	0	14	0	0	0	0	4
react5	0	4	0	0	14	11	0	0	4	0
accept2	11	0	12	23	**86**	**100**	21	9	0	15
foodloss	4	0	9	9	**57**	**67**	12	3	0	11
drool1	7	0	9	17	**71**	**100**	29	9	0	7
drool2	0	0	3	0	0	0	0	0	0	4
seq1	0	0	9	**43**	**100**	**100**	**44**	0	0	11
seq2	0	0	0	3	**43**	**44**	6	0	0	0
seq3	0	0	0	0	29	**44**	0	0	0	0
init1	**44**	0	**33**	20	**57**	**56**	27	**42**	0	**33**
init3	0	0	0	3	**86**	11	0	0	**100**	0
init4	7	**100**	3	0	**86**	11	0	6	0	4
lip1	11	0	12	**91**	**86**	**89**	**94**	9	0	15
lip2	7	0	21	**83**	**86**	**89**	**85**	6	0	26
lip3	**30**	0	29	**100**	**100**	**100**	**94**	24	0	**37**
lip4	0	0	15	**40**	14	**33**	**47**	0	0	18
lip7	0	0	3	6	29	11	3	0	0	4
lip8	10	0	**91**	**77**	**100**	**100**	**79**	12	0	**100**
lip9	**100**	0	9	**34**	**100**	**89**	**35**	**88**	0	0
lip10	19	0	**50**	**86**	**100**	**100**	**91**	18	0	**59**

lip11	11	0	6	**71**	**100**	**89**	**62**	6	0	7
lip12	**63**	0	**74**	**94**	**100**	**100**	**91**	**49**	0	**93**
ton10	0	0	**41**	6	**86**	**33**	12	21	0	26
ton11	0	0	6	**46**	29	**44**	**47**	0	0	7
ton12	0	0	24	**31**	**86**	**33**	29	3	0	26
ton13	0	0	24	20	29	11	18	18	0	7
ton14	0	0	0	0	29	11	0	0	0	0
ton15	0	0	0	0	29	11	0	0	0	0
jaw1	15	0	15	**46**	**86**	**89**	**41**	9	0	19
jaw2	0	0	0	17	**86**	**89**	24	0	0	0
jaw3	0	0	0	9	**86**	**89**	3	0	0	0
jaw4	0	0	0	9	0	0	20	0	0	0
jaw5	4	0	0	0	29	11	0	3	0	0
jaw8	0	0	6	0	**71**	**56**	3	0	0	7
jaw9	7	0	3	3	**86**	**56**	3	6	0	4
jaw10	4	0	0	9	**71**	**33**	6	3	0	0
jaw11	0	0	0	3	**43**	**33**	6	0	0	0
jaw12	11	0	0	3	29	11	6	9	0	0
swal8	0	0	0	0	29	**33**	0	0	0	0
swal9	0	0	0	3	**43**	**56**	3	0	0	0
swal10	0	0	0	0	29	22	0	0	0	0
swal11	0	0	0	0	29	22	0	0	0	0
Total behaviours failed (n=45)	4	1	5	14	28	31	14	3	1	5

The numbers in bold indicate the behaviours failed by more than 30% of that cluster. As in the development study the proportion of behaviours failed by 30% or more of the cluster members varied from cluster to cluster. Shaded columns indicate the clusters with the highest proportion of behaviours failed

by both sample one and sample two. The darker shading shows the clusters for both samples which contain the highest proportion of failed behaviours. For example, in sample one, 31 of the behaviours were failed by 30% or more of the members of that cluster. In sample two, 27 of the tested behaviours were failed by 30% or more members of that cluster. In contrast only 5 of the behaviours in cluster C were failed by members of sample one and 3 by members of sample two.

Identification of normal and abnormal clusters, ranking and cluster membership

Summarised in the final row of table 3 are the number of behaviours failed by 30% or more of the members of that cluster for both sample one and sample two. They range from 1 behaviour failed out of the total 45 DOM behaviours entered into the analysis, to 31 failed behaviours. Again this indicated a far greater range of abnormality in those clusters with higher numbers of failed behaviours. Clusters were ranked according to the number of discrete oral motor behaviours failed by 30% or more of the cluster members according to the procedure adopted in the development study. Tables 4 and table 5 show the cluster rankings for both sample one and sample two with cluster membership crosstabulated by status. The results shown are for the OMC category purée.

There is very little variation in the membership of the abnormal clusters. Equal numbers of both the NOFT and comparison children appear in the

abnormal clusters. In sample one, 12 of the 13 children with cerebral palsy appear in the abnormal clusters whilst all 13 belonged to the abnormal clusters for sample two. Tables 6 through to 17 show the cluster ranking for the remaining 6 OMC categories and the status of the cluster members. The cluster labels (A to E) are given in the first column and were arbitrarily assigned.

Table 4. Cross tabulation of cluster membership (diagnostic categories) by rank position of abnormality for **sample one (Purée).**

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	3	5	21	1
B	Normal	1	12	12	0
C	Normal	2	14	20	0
D	Abnormal	4	24	5	6
E	Abnormal	5	1	0	6

Table 5. Cross tabulation of cluster membership (diagnostic categories) by rank position of abnormality for **sample two (Purée)**.

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Abnormal	5	1	0	8
B	Abnormal	4	24	5	5
C	Normal	2	6	27	0
D	Normal	1	12	12	0
E	Normal	3	13	14	0

Table 6. Cross tabulation of cluster membership (diagnostic categories) by rank position of abnormality for **sample one (semi-solids)**.

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	1	8	23	0
B	Normal	3	22	12	2
C	Normal	2	11	19	2
D	Abnormal	4	4	0	8
E	Abnormal	5	11	4	1

Table 7. Cross tabulation of cluster membership by rank position of abnormality for **sample two (semi-solids)**.

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	2	11	25	0
B	Normal	3	22	10	1
C	Normal	1	11	19	2
D	Abnormal	5	12	4	3
E	Abnormal	4	0	0	7

Table 8. Cross tabulation of cluster membership (diagnostic categories) by rank position of abnormality for **sample one (solids)**

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	3	13	14	0
B	Normal	1	17	21	1
C	Abnormal	4	10	5	7
D	Abnormal	5	10	5	4
E	Normal	2	6	13	1

Table 9. Cross tabulation of cluster membership by rank position of abnormality for **sample two (solids)**.

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	2	19	27	0
B	Normal	1	17	21	2
C	Normal	3	7	4	0
D	Abnormal	5	10	5	6
E	Abnormal	4	3	1	5

Table 10. Cross tabulation of cluster membership (diagnostic categories) by rank position of abnormality for **sample one (cracker)**.

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	2	15	21	1
B	Normal	1	17	23	4
C	Abnormal	4	11	10	2
D	Normal	3	13	4	2
E	Abnormal	5	0	0	4

Table 11. Cross tabulation of cluster membership by rank position of abnormality for **sample two (cracker).**

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Abnormal	5	0	0	9
B	Normal	3	12	2	3
C	Normal	1	17	24	1
D	Normal	2	16	22	0
E	Abnormal	4	11	10	0

Table 12. Cross tabulation of cluster membership (diagnostic categories) by rank position of abnormality for **sample one (bottle)***

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	1	23	17	1
B	Normal	2	23	37	0
C	Abnormal	5	5	2	6
D	Abnormal	3	4	1	5
E	Abnormal	4	1	1	1

* the three abnormal clusters were used to create the index

Table 13. Cross tabulation of cluster membership by rank position of abnormality for **sample two (bottle)***.

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	1	23	16	2
B	Normal	2	27	39	3
C	Abnormal	4	0	0	3
D	Abnormal	5	5	2	4
E	Abnormal	3	1	1	1

* the three abnormal clusters were used to create the index

Table 14. Cross tabulation of cluster membership (diagnostic categories) by rank position of abnormality for **sample one (trainer cup)***

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Abnormal	5	12	6	2
B	Normal	2	15	11	2
C	Normal	4	23	24	5
D	Normal	3	2	0	0
E	Normal	1	4	17	4

* only one cluster was used to create the index

Table 15. Cross tabulation of cluster membership by rank position of abnormality for **sample two (trainer cup)**.

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Abnormal	5	12	6	1
B	Normal	3	15	11	0
C	Normal	2	23	24	10
D	Normal	4	2	0	0
E	Normal	1	4	17	2

Table 16. Cross tabulation of cluster membership (diagnostic categories) by rank position of abnormality for **sample one (cup).**

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	3	25	14	9
B	Normal	2	15	22	0
C	Normal	1	13	15	1
D	Abnormal	5	3	6	2
E	Normal	4	0	1	1

Table 17. Cross tabulation of cluster membership by rank position of abnormality for **sample two (cup).**

Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
A	Normal	4	23	16	7
B	Normal	2	17	21	0
C	Normal	1	13	15	1
D	Abnormal	5	3	5	5
E	Normal	3	0	1	0

Characteristics of the DOM behaviours that discriminate the normal from abnormal clusters

The next step in the analysis was to compare the behaviours that differentiated the abnormal clusters from the normal clusters. To do so the abnormal clusters were amalgamated to form one abnormal cluster and the normal clusters merged to form one large normal cluster. Table 18 shows the percentage of children from each subject group who fell into these amalgamated clusters for both sample one and sample two. For purée, the results are identical for both the comparison and the NOFT subjects with only a minor difference in the subjects with cerebral palsy.

Table 18. **Purée**. Proportion of children in normal/abnormal cluster designation according to status

	NOFT		Comparison		Cerebral Palsy	
	Cluster designation					
Sample	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	31 (55%)	25 (45%)	53 (91%)	5 (9%)	1 (8%)	12 (92%)
2	31 (55%)	25 (45%)	53 (91%)	5 (9%)	0	13 (100%)

Tables 19 to 24 show the proportions of children belonging to normal and abnormal clusters according to their status. The results for semi-solids and cracker are almost identical with some slight variation in the solid texture.

Table 19. **Semi-solids**. Proportion of children in normal/abnormal cluster designation according to status.

	NOFT		Comparison		Cerebral Palsy	
	Cluster designation					
Sample	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	41 (73%)	15 (27%)	54 (93%)	4 (7%)	4 (31%)	9 (69%)
2	44 (79%)	12 (21%)	54 (93%)	5 (7%)	3 (23%)	10 (77%)

Table 20. **Solids.** Proportion of children in normal/abnormal cluster designation according to status.

	NOFT		Comparison		Cerebral Palsy	
	Cluster designation					
Sample	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	36 (64%)	20 (36%)	48 (83%)	10 (17%)	2 (15%)	11 (85%)
2	43 (77%)	13 (23%)	52 (90%)	6 (10%)	2 (15%)	11 (85%)

Table 21. **Cracker.** Proportion of children in normal/abnormal cluster designation according to status.

	NOFT		Comparison		Cerebral Palsy	
	Cluster designation					
Sample	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	45 (80%)	11 (20%)	48 (83%)	10 (17%)	6 (46%)	7 (54%)
2	45 (80%)	11 (20%)	48 (83%)	10 (17%)	4 (31%)	9 (69%)

Table 22. **Bottle.** Proportion of children in normal/abnormal cluster designation according to status.

	NOFT		Comparison		Cerebral Palsy	
	Cluster designation					
Sample	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	46 (82%)	10 (18%)	53 (91%)	5 (9%)	1 (8%)	12 (92%)
2	50 (89%)	6 (11%)	55 (95%)	3 (5%)	5 (38%)	8 (62%)

Table 23. Trainer-cup. Proportion of children in normal/abnormal cluster designation according to status.

	NOFT		Comparison		Cerebral Palsy	
	Cluster designation					
Sample	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	44 (79%)	12 (21%)	52 (90%)	6 (10%)	11 (85%)	2 (15%)
2	44 (79%)	12 (21%)	52 (90%)	6 (10%)	12 92%)	1 (8%)

Table 24. **Cup.** Proportion of children in normal/abnormal cluster designation according to status.

	NOFT		Comparison		Cerebral Palsy	
	Cluster designation					
Sample	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
1	53 (95%)	3 (5%)	51 (88%)	7 (12%)	10 (77%)	3 (23%)
2	53 (95%)	3 (5%)	53 (91%)	8 (9%)	8 (62%)	5 (38%)

Having established that the 'seeded' cluster analysis grouped the subjects in an almost identical manner for the majority of OMC-categories for both sample one and sample two, the next step was to compare the behaviours which discriminated the normal from the abnormal clusters.

Summary of DOM behaviours which discriminate normal from the abnormal clusters

The same procedure as outlined in the development study was adopted to establish a list of behaviours that distinguished the normal clusters from the abnormal clusters. Table 25 illustrates the procedure for the OMC category purée for sample two. Only a subset of the 45 behaviours entered into the analysis is shown to demonstrate the procedure.

The behaviours failed by 30% or more of the clusters are highlighted in bold. The behaviours that distinguish the abnormal clusters (clusters A and B) from the normal clusters are shaded (lighter shading). For example, 78% of cluster A and 35% of cluster B members failed on the oral motor behaviour react 1. This same behaviour was failed by very few members of clusters C, D or E. A similar result can also be seen for sequencing 1, lip 1 and lip 2. There were other behaviours that were failed by a large proportion of members of the most abnormal cluster (cluster A) but by very few or none of the other cluster members (indicated by darker shading). For example, 89% of cluster A members failed on react 3, whereas only 18% failed the behaviour in cluster B (the second most abnormal cluster) and very few

individuals failed this behaviour in clusters C, D or E (the normal clusters). The same pattern can be seen for a number for other behaviours, such as accept 2, foodloss, sequence 2 and sequence 3.

Other behaviours were failed by many members of many clusters. For example, 56% of cluster A, 42% of cluster C and 33% of cluster E failed on initiation 1. A similar pattern was found for a few other behaviours not illustrated in the table. That is, occasionally behaviours were failed by 30% or more of the members of clusters other than those designated as abnormal. Such behaviours were not considered to provide adequate discrimination between normal and abnormal clusters.

Only those behaviours that discriminated the two most abnormal clusters from the normal clusters were included in the screening version of the SOMA in the development study. However, as part of the validation study it was also of interest to know how effective the use of other behaviours might be. For example, an alternative index could be formed by using the behaviours that discriminate the most abnormal cluster from all others or a combination of different indexes. This will be further developed later in this chapter. The index that was formed from those behaviours that discriminated the two abnormal from the normal clusters will be known as index a.

Table 25 Cluster membership showing proportion of members of individual clusters failing a subset of DOM behaviours.

Cluster	A	B	C	D	E
react 1	**78**	**35**	3	0	15
react 2	**89**	18	0	0	4
react 3	**78**	18	0	0	0
react 4	0	0	0	0	4
accept 2	**100**	21	9	0	15
food loss	**67**	12	3	0	11
drool 1	**100**	29	9	0	7
drool 2	0	0	0	0	4
sequence1	**100**	**44**	0	0	11
sequence2	**44**	6	0	0	0
sequence3	**44**	0	0	0	0
initiation 1	**56**	27	**42**	0	**33**
lip 1	**89**	**94**	9	0	15
lip 2	**89**	**85**	6	0	26
lip 4	**33**	**47**	0	0	18
lip 11	**89**	**62**	6	0	7
tongue 11	**44**	**47**	0	0	7
tongue 12	**33**	29	3	0	26
jaw 1	**89**	**41**	9	0	19
jaw 2	**89**	24	0	0	0
jaw 3	**89**	3	0	0	0
jaw 8	**56**	3	0	0	7
jaw 9	**56**	3	6	0	4
jaw 10	**33**	6	3	0	0
jaw 11	**33**	6	0	0	0
swallow 8	**33**	0	0	0	0
swallow 9	**56**	3	0	0	0

Comparison of index a generated on both sample one and two

The indices generated on both sample one and sample two are shown in table 26 for the OMC category purée. The indices are remarkably similar. Index 1a (sample one) contains 9 behaviours whereas index 2a (sample two) contains 8 behaviours. Only 3 behaviours are not common to both groups (lip 3, lip 4 and tongue 12).

Table 26 :**Purée.** The behaviours which form index 1 for both sample one and two.

Sample one	**Sample two**
Index 1	**Index 2**
React 1	React 1
Sequencing 1	Sequencing 1
Lip 1	Lip 1
Lip 2	Lip 2
Lip 3	
	Lip 4
Lip 11	Lip 11
Tongue 11	Tongue 11
Jaw 1	Jaw 1
Tongue 12	
Total : 9	**Total: 8**

Tables 27 through to 32 show the behaviours that formed the screening indices for the remaining OMC categories generated on both samples one and two. Behaviours that are common to both indices are highlighted by the shading.

Table 27: **Semi-solids**. The behaviours which form index 1a and 2a

Sample one	**Sample two**
Index 1a	**Index 2a**
Drool 1	Drool 1
Sequencing 1	Sequencing 1
Initiation 3	
Lip 13	Lip 13
Jaw 1	Jaw 1
Jaw 2	Jaw 2
Jaw 3	Jaw 3
Jaw 10	
	Tongue 11
	Jaw 4
	Jaw 8
	Jaw 9
	Jaw 11
Total : 8	**Total: 11**

DOM behaviours that form the screening indices for sample one and sample two. There were 8 behaviours from sample one and 11 from sample two. The shaded rows indicate the 6 DOM behaviours that were common to both indices.

Table 28 : **Solids** The behaviours which form index 1a and 2a.

Sample one	**Sample two**
Index 1a	**Index 2a**
Food loss 1	Food loss 1
Drool 1	Drool 1
Jaw 1	Jaw 1
Sequencing 1	
Lip 1	
Lip 2	
Lip 4	
Lip 11	
Tongue 10	
	React 1
	React 2
	React 3
	React 4
	Sequencing 2
	Initiation 1
	Jaw 2
	Jaw 4
	Jaw 5
	Jaw 9
	Swallow 9
	Swallow 10
Total : 9	**Total: 15**

Table 28 illustrates the DOM behaviours that form the index for sample one and sample two. There were 9 behaviours from sample one and 15 from sample two. Only 3 behaviours were common to both indices as indicated by

the shaded rows.

Table 29 : **Cracker.** Behaviours which form index 1a and 2a.

Sample one	**Sample two**
Index 1a	**Index 2a**
Initiation 1	
Drool 1	Drool 1
Drool 2	Drool 2
Food loss 1	Food loss 1
	Lip 2
Lip 4	Lip 4
Lip 7	Lip 7
Lip 9	Lip 9
Tongue 10	Tongue 10
Tongue 11	Tongue 11
Tongue 12	Tongue 12
Tongue 13	Tongue 13
Jaw 2	Jaw 2
Jaw 3	Jaw 3
Jaw 4	Jaw 4
Jaw 5	Jaw 5
Jaw 8	Jaw 8
Jaw 9	Jaw 9
Jaw 11	Jaw 11
Jaw 12	Jaw 12
Swallow 9	Swallow 9
Bite 5	
Bite 8	
Bite 12	Bite 12
Total : 23	**Total: 21**

In table 29, the 22 behaviours which formed the index generated on sample one and the 18 behaviours which formed the index from sample two are illustrated. The highlighted rows show the 16 behaviours that were common to both indices.

Table 30 : **Bottle.** Behaviours which form index 1a and 2a.

Sample one	**Sample two**
Index 1a	**Index 2a**
React 2	
React 4	
Accept 2	
Lip 3	
Lip 5	Lip 5
Lip 6	Lip 6
Lip 7	
Jaw 1	
Sequencing 1	
	React 1
	React 3
	Liquid loss 1
	Tongue 10
	Tongue 11
	Jaw 4
	Swallow 9
	Swallow 11
	Sequencing 2
Total : 9	**Total: 16**

Table 30 shows the DOM behaviours that formed the index for both sample one and sample two. Nine behaviours make up the index generated on sample one and 11 for sample two. Only two behaviours are common to both indices.

Table 31 : **Trainer cup**. Behaviours which form index 1a and 2 a.

Sample one	**Sample two**
Index 1a	**Index 2a**
Liquid loss 2	Liquid loss 2
Sequencing 2	Sequencing 2
Sequencing 3	Sequencing 3
	Lip 7
Tongue 10	Tongue 10
Tongue 11	Tongue 11
Jaw 1	Jaw 1
Jaw 6	Jaw 6
Jaw 10	Jaw 10
Jaw 12	Jaw 12
Swallow 1	Swallow 1
Swallow 4	Swallow 4
Swallow 5	Swallow 5
Swallow 6	Swallow 6
Swallow 7	Swallow 7
Total : 14	**Total: 15**

There are 14 DOM behaviours in index 1a (sample one) and 15 in index 2a (sample two). The indices are identical but for one behaviour

occurring in index 2a but not in index 1a as is illustrated by the shaded columns.

Table 32 :**Cup**. Behaviours which form index 1a and 2 a.

Sample one	**Sample two**
Index 1a	**Index 2a**
	React 1
	React 2
	React 3
Accept 2	Accept 2
Sequencing 2	Sequencing 2
Sequencing 3	Sequencing 3
Tongue 10	Tongue 10
Tongue 11	Tongue 11
Jaw 1	Jaw 1
Jaw 4	Jaw 4
Swallow 9	Swallow 9
Liquid loss 2	
Total : 9	**Total: 11**

Table 32 shows the 9 behaviours which form index 1a and 11 behaviours for index 2a. Eight behaviours, as indicated by the row shading are common to both indices.

Comparison of the effectiveness of the indexes generated on both sample one and sample two

In the development study a provisional abnormality score was devised based on the subsets of DOM behaviours shown for sample one in tables 26 to 32. This was termed the 'total dysfunction score'. A high score would indicate greater abnormality and membership of an abnormal cluster, whereas a low score, membership of a normal cluster. Cut off points for each oral motor challenge category were devised. A score above the cut off point would predict membership of an abnormal cluster and below the cut off point, membership of a normal cluster. In table 33 the relationship between the total dysfunction scores (OMC category purée) are given for both index 1a and 2a. In the development study a cut off score of >2 was used and also adopted for sample two. Using this cut off point it is possible to study the number of children in both the normal and abnormal clusters who score above and below this point.

Table 33. The relationship between total dysfunction scores obtained by individual children on the screening indexes 1a and 2a and cluster membership for purée.

Total dysfunction score*	Index 1a		Index 2a	
	Abnormal clusters	Normal clusters	Abnormal clusters	Normal clusters
0	0	46	0	55
1	0	19	0	20
2	1	16	2	5
3	2	1	8	3
4	7	3	7	1
5	8	0	11	0
6	9	0	7	0
7	7	0	7	0
8	7	0	1	0
9	1	0		
	Maximum score: 9	Maximum score: 9	Maximum score: 8	Maximum score: 8

*Cutting score of 3 or more indicates an abnormal score on Purée

By studying table 33 it is clear that the majority of children in abnormal clusters for both sample one and sample two score above the cut off, whereas the majority of children in the normal clusters score below the cut off.

The efficiency of the separate indexes as screening procedures to predict group membership can now be tested. As in the development study the sensitivity of the screening instrument, that is, the proportion of true cases or true positive rate, the positive predictive value - the probability that a screen-

positive is truly a case and the specificity of the screening instrument were calculated. In chapter 4 an example of how the positive predictive value, sensitivity and specificity were calculated. In table 34 these calculations are given for both samples one and two. The indices for both samples give excellent discrimination.

Table 34: Purée. Efficiency of the screening procedure (index 1a and 2a) in predicting group membership.

Predicted group membership Index 1a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	Normal			
Abnormal	41	4	.91	.98	.95
Normal	1	81			
Predicted group membership Index 2a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	Normal			
Abnormal	41	4	.91	.95	.95
Normal	2	80			

Tables 35 through to 40 show the relationship between the total dysfunction scores for both index 1a and 2a and give the sensitivity, specificity and positive predictive value calculations for the remaining OMC categories.

Table 35: Semi-solids. Efficiency of the screening procedure in predicting group membership for both sample one and sample two.

Predicted group membership Index 1a	Actual group membership		Positive predictive value	Sensitivity	Specificity
	Abnormal	Normal			
Abnormal	25	8	0.76	0.89	0.92
Normal	3	91			
Predicted group membership Index 2a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	Normal			
Abnormal	26	1	0.96	1	0.99
Normal	0	100			

The values of the screening index for sample two are higher than those obtained for sample one for the OMC category semi-solids.

Table 36: **Solids**. Efficiency of the screening procedure in predicting group membership for both sample one and sample two.

Predicted group membership Index 1a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	**Normal**			
Abnormal	38	2	0.95	0.93	0.98
Normal	3	84			
Predicted group membership Index 2a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	**Normal**			
Abnormal	27	2	0.96	0.9	0.99
Normal	0	96			

The positive predictive value, sensitivity and specificity are almost identical for both samples.

Table 37: **Cracker**. Efficiency of the screening procedure in predicting group membership for both sample one and sample two.

Predicted group membership Index 1a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	Normal			
Abnormal	27	0	1.0	1	1
Normal	0	100			
Predicted group membership Index 2a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	Normal			
Abnormal	30	0	1	1	1
Normal	0	97			

The PPV, sensitivity and specificity obtained for both samples were equal to 1, indicating that the screening index gave perfect discrimination.

Table 38: **Bottle**. Efficiency of the screening procedure in predicting group membership for both sample one and sample two.

Predicted group membership Index 1a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	Normal			
Abnormal	26	1	0.96	0.96	0.99
Normal	1	99			
Predicted group membership Index 2a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	Normal			
Abnormal	14	2	0.87	0.87	0.98
Normal	2	109			

The PPV, and sensitivity of the index generated on sample one were slightly higher than those obtained for sample two. The specificity values for both indices were similar.

Table 39: **Trainer-cup**. Efficiency of the screening procedure in predicting group membership for both sample one and sample two.

Predicted group membership Index 1a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	Normal			
Abnormal	20	0	1	1	1
Normal	0	107			
Predicted group membership Index 2a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	Normal			
Abnormal	19	0	1	1	1
Normal	0	108			

The PPV, sensitivity and specificity values obtained for both indices was equal to 1, indicating perfect discrimination.

Table 40: **Cup**. Efficiency of the screening procedure in predicting group membership for both sample one and sample two.

Predicted group membership Index 1a	Actual group membership		Positive predictive value	Sensitivity	Specificity
	Abnormal	Normal			
Abnormal	11	1	0.92	0.85	0.99
Normal	2	113			
Predicted group membership Index 2a	**Actual group membership**		**Positive predictive value**	**Sensitivity**	**Specificity**
	Abnormal	**Normal**			
Abnormal	10	0	1.0	1.0	1.0
Normal	0	117			

The PPV, sensitivity and specificity values obtained for sample two were higher than those obtained on sample one, indicating that index 2 would provide slightly better discrimination.

In table 41 the mean scores obtained by each of the groups is shown for each OMC category and each sample. Using a oneway analysis of variance the mean scores obtained by each group were compared. Without exception, children with CP obtained the highest scores. With the exception of the OMC category trainer-cup (both sample one and 2) and cup (sample one only), the mean scores of the children with CP differed significantly from both the children with NOFT and the comparison subjects for the majority of OMC categories (see darker shaded columns - purée, semi-solids, solids, cracker and bottle). Children with NOFT tended to score higher than the comparison subjects. For the OMC categories purée and semi-solids the mean scores of

the children with NOFT differed significantly from the comparison subjects.

Forty-five per cent of the children who were failing to thrive scored above the threshold for purée whereas all the subjects with CP did so. The mean scores of the children with FTT who scored above the threshold were compared with the children with CP. Only the solid foodstuffs were included because they tended to provide far better discrimination than the liquids. The mean scores are shown in table 42 and significant differences indicated.

For both sample one and two there were significant differences between the FTT and CP abnormality scores for purée, with the CP children achieving higher scores. The only other significant difference was for semi-solids (sample one only) where the children with FTT scored significantly higher then the children with CP.

Table 41. The mean scores for the OMC category screening indices for each of the three groups studied.

OMC category	Purée		Semi-solids		Solids		Cracker		Bottle		Trainer-cup		Cup	
Sample	**one**	**two**	**one**	**two**	**one**	**two**	**one**	**two**	**one**	**two**	**one**	**two**	**one**	**two**
Group 1 Comparison	1.0	.75	.93	1.4	1.6	1.5	4.5	4.2	.79	.94	1.6	1.8	1.3	0.9
Group 2 NOFT	2.8	2.3	2.0	3.1	2.7	2.6	5.3	4.9	1.3	1.6	3.2	3.5	1.3	0.6
Group 3 CP	6.9	6.3	4.1	7.5	7.0	10.6	11.1	15.1	5.7	8.9	3.3	4.4	2.9	6.0
Group 3 significantly different from 1 and 2*														
Group 2 significantly different from 1*														

* ANOVA (Scheffe procedure) significant at 0.05 level. Shading indicates significant results.
columns - purée, semi-solids, solids, cracker and bottle). Children with NOFT tended to score higher than the comparison subjects. For the OMC categories purée and semi-solids the mean scores of the children with NOFT differed significantly from the comparison subjects.

Table 42: Mean (sd) abnormality scores of the children with FTT and CP who scored above the threshold for each OMC category.

OMC category	Sample one			Sample two		
	FTT	CP	p value	FTT	CP	p value
Purée	5.2 (1.3)	7.3 (1.3)	*	4.4 (1.2)	6.3 (0.9)	*
Semi-solids	7.4 (0.5)	6.0 (1.1)	*	9.4 (2.3)	8.8 (1.6)	ns
Solids	7.0 (1.7)	7.8 (0.9)	ns	9.4 (3.1)	11.5 (3.0)	ns
Cracker	20.4 (3.9)	22.3 (1.0)	ns	19.3 (3.0)	18.6 (3.4)	ns

* significant at 0.05 level (t-test for independent samples)
ns not significant

Further development and application of the screening instrument

Introduction

In addition to further validating the screening instrument it was also of interest to explore the use of the indices and consider alternative methods of developing indices. Table 43 shows the derivation of other possible ind which will be developed and the results presented in the remaining section of this chapter. The first indices developed (1a and 2a) were summarised and described in the first section of this chapter.

Table 43: Derivation of the indices developed on both sample one and 2.

Sample one		Sample two	
Index	**Derivation**	**Index**	**Derivation**
1a	behaviours which discriminate the 2 most abnormal clusters from all others	2a	behaviours which discriminate the 2 most abnormal clusters from all others
1b	behaviours which discriminate the most abnormal cluster from all others	2b	behaviours which discriminate the most abnormal cluster from all others
1c	combined index (1a + 1b)	2c	combined index (2a + 2b)
1d	switching indices (running 2a on sample one)	2d	switching indices (running 1a on sample two)
1e	combined index (1a + 2a)	2e	combined index (2a + 1a)

Procedures for further development of the Indices

Index 1b and 2b

In both the development and validation studies only one index (index 1a) was developed as a screening instrument. This index was derived from the behaviours which discriminated the two most abnormal clusters from the normal clusters apart from two OMC categories, (cup and trainer-cup) where only the behaviours that discriminated the most abnormal cluster from all others was used. In table 24 the manner in which the screening instrument was devised for the majority of OMC categories for both sample one and sample two was demonstrated. However, by studying this table it is clear that there were also a number of behaviours which were failed by members of the most abnormal cluster and by very few or none of the other cluster members. For example, react 2, react 3, jaw 3 and swallow 9, were all failed by the majority of cluster A members (the most abnormal cluster) and by very few or none of the other clusters. Even the cluster members of the next most abnormal cluster (cluster B), failed very few of these behaviours.

The development of the screening instrument did not take into account the behaviours which discriminated the most abnormal cluster from all others. Presumably this list of behaviours would identify the most abnormal children from all others. In most instances if these behaviours were used as a screening instrument, it would only identify a small proportion of children. By studying the ranking of clusters and status of the cluster members (see tables 3 to 16) it is clear that the majority of cases identified were those with

cerebral palsy. Table 44 shows the list DOM behaviours (purée) from both sample one and sample two which could be used to form such a screening index (the index has been labelled index b, index 1b for sample one and 2b for sample two). That is, if the behaviours that discriminate the most abnormal from all other clusters were used.

Table 44: **Purée**. The behaviours that form index b for both sample one and 2.

Sample one	**Sample two**
Index 1b	**Index 2b**
	React 2
	React 3
Accept 2	Accept 2
Food loss	Loss
drool 1	Drool 1
Sequence 2	Sequence 2
	Sequence 3
Init 3	
	Tongue 10
	Tongue 12
Jaw 2	Jaw 2
Jaw 3	Jaw 3
	Jaw 8
Jaw 9	Jaw 9
Jaw 10	Jaw 10
Jaw 11	Jaw 11
	Swallow 8
Swallow 9	Swallow 9
Total : 11	**Total: 17**

As for the first screening index developed, a different number of behaviours form each index, although the majority of behaviours are very similar. The shaded areas show the behaviours common to both samples.

In table 45 the relationship between the total dysfunction scores and cluster membership is shown. Taking a cut-off point of 3 or more it is clear that for both samples, a number of abnormal cluster members for both samples would score in the normal range, whereas no normal cluster members would achieve an abnormal score.

In table 46, the sensitivity, positive predictive value and specificity of the index has been calculated using the same methodology as outlined in both the development study and described earlier in this chapter. The calculations were computed using a cutoff score of 3 or less. By manipulating the cutoff scores for sample two it is possible to raise the positive predictive value and specificity of the screening test at the expense of lowering the sensitivity. The specificity and positive predictive value of index b are excellent, that is, it accurately predicts the true negative rate and the probability that a screen positive is truly a case. However, the sensitivity of this index as a screening instrument is unacceptable as only 46% of the true positives were identified. Therefore, whilst the behaviours that form index b are of clinical significance the use of index b as a screening instrument would not be satisfactory. The use of index b as a screening instrument was not therefore pursued for the other OMC categories.

Table 45. The relationship between total dysfunction scores obtained by individual children on index b and cluster membership (that is normal or abnormal) for both sample one and sample two.

Total dysfunction score	Sample one		Sample two	
	Abnormal clusters	Normal clusters	Abnormal clusters	Normal clusters
0	24	79	9	53
1	6	4	12	19
2	3	2	2	10
3	1	0	3	2
4	2	0	5	0
5	2	0	1	0
6	1	0	0	0
7	2	0	2	0
8	0	0	3	0
9	1	0	1	0
10			1	0
11			1	0
12			0	0
13			2	0
14			1	0
	Maximum score: 11	Maximum score: 11	Maximum score: 17	Maximum score: 17

Scores greater than or equal to 4 were abnormal whilst those less than 4 were normal.

Table 46: Purée. Efficiency of the screening procedure using index b* to predict group membership for both sample one and sample two.

Predicted group membership sample one	**Actual group membership**		Positive predictive value	Sensitivity	Specificity
	Abnormal	Normal			
Abnormal	9	0	1	0.27	1
Normal	33	85			
Predicted group membership sample two	**Actual group membership**		Positive predictive value	Sensitivity	Specificity
	Abnormal	Normal			
Abnormal	20	2	0.9	0.46	0.98
Normal	23	82			

* index b was generated by using the behaviours that discriminate the most abnormal clusters from all other clusters.

Formulating a combined index for each sample

Another possibility was to formulate a combined index from each sample. That is to add together index a and index b. In other words the behaviours that formed index a, that is, those behaviours that discriminated the 2 abnormal clusters from all others could be merged with those that formed index b, the index formed from behaviours that discriminated the single most abnormal cluster from all others. However, whilst this might give an all encompassing index, the sensitivity, specificity and positive predictive values of index a for both sample one and two were excellent. Such an exercise might therefore increase these values slightly but would make the screening

instrument a great deal longer and more time consuming to administer and score. Once again this was not pursued for any of the OMC categories.

Applying the indexes to independent samples

The primary interest in further validating the screening version of the SOMA was to investigate the discriminatory power of the indexes generated on independent samples of children known to have oral motor deficits as a result of cerebral palsy. In other words would the screening version of the SOMA still differentiate between normal and abnormal cluster membership with equal efficiency. This was known to be the case for the majority of the OMC categories. However, the discrete oral motor behaviours that formed some of the indexes generated on each sample did in fact differ for some of the OMC categories. Whilst this may not be of major significance if the indexes differed on only a small number of behaviours, however, it would if a large proportion of the behaviours that formed each index were different. This would be particularly important in deciding which index was the most effective in using as a screening tool. In part it could be decided on the basis of the greatest efficiency in terms of the PPV, sensitivity and specificity of the index, however as can be seen from tables 33-39 these differ very little for most of the OMC categories.

A further step was therefore considered which involved applying each index to the opposite sample. For example, index 1a was generated on sample one. If this index was applied to sample two would the same discriminatory

power be obtained. In effect this involved switching the indices from one sample to another. In table 46 the results are shown for the OMC category purée.

Table 47: Purée. Efficiency of the screening procedure using index a to predict group membership for both sample one and sample two. Index 1a was applied to sample two and index 2a to sample one.

Predicted group membership Sample one Index 2a	Actual group membership		Positive predictive value	Sensitivity	Specificity
	Abnormal	Normal			
Abnormal	40	4	.95	.91	.95
Normal	2	81			
Predicted group membership Sample two Index 1a	Actual group membership		Positive predictive value	Sensitivity	Specificity
	Abnormal	Normal			
Abnormal	40	3	0.93	0.93	0.97
Normal	3	81			

In table 48 the results of switching the indices from the sample they were generated on to the other sample for the remaining OMC categories are shown. The PPV, sensitivity and specificity values for each index are illustrated.

Table 48. The PPV, sensitivity and specificity of the indices when switched from the sample on which they were originated. Index 1a generated on sample one was switched to sample two and index 2a, generated on sample two was switched to sample two.

	Sample one*			Sample two**		
OMC category	**PPV**	**Sensitivity**	**Specificity**	**PPV**	**Sensitivity**	**Specificity**
Semi-solids	.95	.82	.95	1.0	.96	1.0
Solids	.75	.86	.94	.93	.93	.97
Cracker	1.0	1.0	1.0	1.0	1.0	1.0
Bottle	.96	.96	.99	.94	.79	.96
Trainer-cup	1.0	1.0	1.0	1.0	1.0	1.0
Cup	1.0	1.0	1.0	1.0	1.0	1.0

* Index 2a generated on sample two was applied to sample one
** Index 1a, generated on sample one was applied to sample two

Formulating a combined index from both samples

A final procedure was undertaken in the development of the indexes or screening behaviours. This involved combining the 2 indexes derived from each sample (eg: index 1a and index 2a) to form a final comprehensive screening index. The combined indexes were then applied independently to each sample. This final step was undertaken to ensure that the best possible screen was used if the discrete oral motor behaviours in the 2 indices derived from the separate samples differed.

Table 49: Purée. Efficiency of the screening procedure using index c (combined index) to predict group membership for both sample one and sample two. Index 1a and 2a were merged and applied to both samples.

Predicted group membership Sample one	**Actual group membership**		Positive predictive value	Sensitivity	Specificity
	Abnormal	Normal			
Abnormal	40	2	.93	.95	.98
Normal	3	82			
Predicted group membership Sample two	**Actual group membership**		Positive predictive value	Sensitivity	Specificity
	Abnormal	Normal			
Abnormal	41	2	0.98	0.93	0.97
Normal	3	81			

In table 50 the PPV, sensitivity and specificity for each OMC category are shown. These results are for the combined index, that is adding the index generated on sample one to that from sample two and applying this index separately to each sample.

Table 50. Summary of the PPV, sensitivity and specificity values for the combined index. Index 1a and index 2a were combined and applied independently to each sample.

	Sample one			Sample two		
OMC category	**PPV**	**Sensitivity**	**Specificity**	**PPV**	**Sensitivity**	**Specificity**
Purée	.93	.95	.98	.98	.93	.97
Semi-solids	.96	.86	.96	1.0	.96	1.0
Solids	.95	.89	.94	.93	.97	.99
Cracker	1.0	1.0	1.0	1.0	1.0	1.0
Bottle	.96	.96	.99	.83	.93	.97
Trainer-cup	1.0	1.0	1.0	1.0	1.0	1.0
Cup	1.0	1.0	1.0	1.0	1.0	1.0

Chapter 6. Discussion

Research aims

The main aim of the study was to develop an instrument capable of objectively rating oral motor skills in children aged between 12 and 24 months. The screening version of the SOMA takes approximately 15-20 minutes to administer and has a relatively simple scoring system with demonstrated reliability and validity making it an attractive tool for both clinical and research use. In order to develop effective treatment protocols and to evaluate the efficacy of their programmes, therapists need objective measures which are standardised for normal developmental function. In the literature review it was clear that not only do very few assessment protocols exist but that almost none have been subjected to rigorous scientific procedures during their development. Throughout the discussion it is my intention to compare, where possible, the development and validation of the SOMA to existing assessment tools. In many cases however, no comparison is possible because of the paucity of material available in the area.

<u>The development of the SOMA</u>

Prerequisites for an assessment of oral motor skills

In chapter 4, the development study, three basic prerequisites were outlined for the development of the SOMA. Each will be discussed in turn.

- First, the assessment of oral motor skills should involve a variety of textures which challenge the child's oral motor skills.

Five oral motor challenge categories (OMC) were included in the final version of the SOMA. The sixth, OMC category, dried fruit, was found to be too challenging for the majority of infants aged 12-18 months, although some as young as 12 months were able to bite and tear a piece off and masticate it satisfactorily. There was a large amount of missing data either because the children refused the OMC category or they were unable to actually manage the texture. The amount of missing data may have been reduced if the dried fruit (which seemed to be outside the experience and preference of many of the children) had been substituted with a different type of food.

Data were also missing from the trials that involved drinking from a straw. Although the majority of infants were unable to successfully manage this task, during the piloting phase it was noted that some children as young as 6-9 months were able to drink from a straw. Whilst some had been exposed to straw drinking previously, others had not, yet were still able to perform the task immediately. The OMC categories dried fruit and straw drinking were therefore dropped from the final version.

The SOMA is the first oral motor assessment schedule to include such a wide range of oral motor challenge categories. Although other schedules do recommend the use of different food textures (eg: Kenny et al 1989) they do not actually include a standardised set of textures in the protocol. Further development of the SOMA should include the provision of a wider range of

foodstuffs that take into account the differing cultural and social eating patterns of young infants in the UK.

In its current form the SOMA is applicable to infants with developmental ages in the 6 to 24 months range. Further development of the OMC categories, (in progress) will be necessary to permit the evaluation of older children. Children aged between 2 and 8 years are currently being assessed with the SOMA in 2 follow-up studies; one involving the children with NOFT assessed in this study.

- Second, the manner in which food and liquid are presented to the child should be standardised. Oral performance varies according to the texture and implement used during feeding.

Criteria were established for the administration of the SOMA (see administration manuals in appendix 3) to assist later ratings of behaviours. Because each behaviour was described in some detail and strict guidelines were given for the method of scoring, there were few problems with this aspect of the study. The inter-rater reliabilities were excellent and the scoring accuracy was aided considerably by the use of the detailed information contained in the scoring manuals. Apart from the work of Kenny and colleagues (1989) and Morris and Klein (1987), detailed descriptions of the oral motor behaviours being assessed are not included in the majority of oral motor schedules.

- The final prerequisite was that a set of utensils be developed to ensure that presentation of the oral motor challenge categories was standard and to assist with scoring.

The equipment developed was modeled on standard infant feeding utensils, but manufactured from transparent materials so that the administrator and rater had as clear a view as possible of the child's oral area (see examples of equipment in appendix 2). Because the SOMA was rated from video recordings the use of the clear utensils made scoring considerably easier. Clinical assessments are concerned with the child's function and use the available resources, that is, the cups, spoons and bottles the child habitually uses. Whilst this may be acceptable in a clinical setting, it is not appropriate in a research setting where it is necessary to keep as many of the confounding variables, such as the type of cup used, constant. Much of the feeding equipment developed for children with severe oral motor difficulties, is designed to make the ingestion of food and liquid as easy as possible. Shaped spoons, cups with special spouts and flow control, all aim to make feeding safer and more comfortable. However, in the study undertaken the use of such utensils would have confounded the results, making it difficult to gain a realistic impression of the child's abilities. For this reason a standard set of utensils was developed and used for all children seen in the study.

Apart from the SOMA no existing assessment of oral motor skills meets the prerequisites summarised above. The multidisciplinary profile developed by

Kenny et al (1989) does include some standardisation in that the items should be administered and scored in a certain manner. It does not however, include a standard set of utensils or textures. This is in part due to the fact that the profile was developed for use with multiply handicapped individuals and did not include any standardisation procedures on a sample of individuals with normally developing oral motor skills. Gisel (1991) describes a standard set of textures she and her colleagues have used in their many studies on emerging chewing function in young children. It is not clear if a standard set of utensils was used or if guidelines were developed for presentation and scoring. It seems reasonable to conclude therefore that much of the inconsistency in the literature as to what behaviours constitute OMD might in part be directly attributed to the fact that many of the assessments used in previous studies have not met the basic prerequisites that have been outlined.

The discrete oral motor behaviours entering the analysis

An exhaustive list of more than 200 oral motor behaviours was compiled for each OMC category. The scoring manuals provided detailed descriptions of each oral motor skill with guidelines as to how each DOM behaviour should be rated. The literature review illustrated that there was little information about the normal development of oral motor skills and even less information about what constituted OMD. Therefore, at this stage in the development of the instrument, decisions were not made as to the status of each behaviour, that is, whether it was considered normal or abnormal. Instead, items were scored as either present or absent.

Rating difficulties

Certain DOM behaviours proved difficult to rate despite the scoring guidelines. There were specific problems in the functional area, tongue movements and the functional unit, swallowing. Behaviours such as tongue tip elevation and lateral tongue movements were often not easily observed, often because the lips were closed. There is however some controversy about the age at which lateral tongue movements emerge; Gisel et al (1991) is of the opinion that only 7% of 2 year old children are proficient in transferring food from side to side, while Morris (1987) states that lateral tongue movements can be observed as early as 6 months. In the SOMA four types of lateral tongue movements were rated (see Table 4 in Reilly et al (1995) in appendix 1). Although these DOM behaviours were not easily observed, on occasions the most mature form, side to side transfer, was seen in the comparison children as young as 12 months. The rather wide age discrepancy reported in the literature could then be related to two factors; first the lack of consistent methods of assessment (such as the standardised administration including a variety of textures) and second the poor description of oral motor behaviours previously used by many researchers.

The discrete oral-motor behaviours which occurred during swallowing were the most difficult to record accurately, and are the subject of a subsequent investigation on the reliability of rating swallowing events in young children. Much of the work of Erika Gisel has been based on measuring what she terms 'food cycles' or the time taken to manipulate food and swallow it.

Cycles are timed from food being placed in the mouth until the swallow is observed. However, the swallow ratings on the SOMA were some of the most unreliable (Reilly et al 1995 in appendix 1). Performance did not seem to vary according to the status of the child, that is whether they had cerebral palsy, were failing to thrive or were developing normally. At times it was impossible to tell from observation alone if and when a child had swallowed at all, although if there was a significant degree of associated OMD with coughing and choking, the latter behaviours could be rated more reliably. Therefore, it seems reasonable to conclude that it is impossible to evaluate swallowing in this age range by observation alone. Whilst observation will alert the experienced clinician to rather obvious pharyngeal abnormalities more subtle defects may go unnoticed. Splaingard et al (1988) have shown that there is poor correlation between observational methods of assessing swallowing, and the findings obtained on more direct methods for evaluating swallowing such as videofluroscopy.

Refusal behaviours

During the observations of the study, refusing to be fed was relatively common, particularly among infants in the 12-18 month age range who were beginning to develop some independence in self feeding. In an attempt to overcome refusals the child was allowed at least one self feeding trial. This trial could then be substituted for any missing data in the examiner administered trials (see Development study. B. Results (2.2) Procedures for dealing with missing data). Refusal behaviours were affected by the OMC

category presented and the presence or absence of any feeding difficulties. Refusals were highest for the spooned solids and dried fruit textures, and lowest for the liquids (bottle, trainer-cup, cup and straw drinking) and medium cracker. Many studies of oral motor functioning fail to mention refusal rates despite the fact that this would seem to be a relatively commonly occurrence in infants. The higher rate for purée may be due to the fact that purée was the first texture administered and had the textures been randomly administered this may have been reduced.

Whilst the aim was to have a range of foods available and make sure that there were at least 2 choices available in each OMC category, some of the foods still were not to the children's taste. A proportion of the children in both the NOFT and control group existed largely on ready prepared baby foods and therefore had limited exposure to other tastes and textures. In the literature review, a sensitive or critical period for the introduction of solid foods was discussed. It is possible that children exposed to a limited range of tastes and textures, might have a higher rate of refusal behaviours, reflecting their unwillingness to attempt new tastes and textures. Although, in retrospect a wider choice of foods for each OMC category might have ensured that there was a suitable choice for some children thereby reducing their rate of refusal behaviours, for others, who were unexposed to a variety of experiences, it may have had no effect .

A further reason why some of the children may have refused could be

attributed to the child's wariness at having a strange adult feed them. Where possible the SOMA assessment was left until the end of the session so that the child was used to the examiner's presence, however some children were more wary than others and possibly refused for this reason. If the carer felt this was the case the mother was given instructions and asked to administer the SOMA and these trials substituted if warranted.

Missing data

By using the procedures described it was possible to maintain the sample size. This was crucial because the cluster analysis required list-wise deletion of cases with missing data. Any subject with missing data, even for one variable, would as a result have been excluded from the analysis. Therefore the first step, prior to commencing any analysis was to reduce the list of DOM behaviours by excluding any behaviour that could not be readily observed and any behaviours that could not be reliably rated. An example of an item that could not easily be observed was 'tongue cupping', and an item that could not be reliably rated was whether or not a swallow was observed. By applying this first step to the data set, the list of variables entering the analysis was reduced. For example, for the OMC category - purée, a total of 64 behaviours could have been entered into the analysis and this was reduced to 45 DOM behaviours for the cluster analysis. This was a satisfactory procedure to undertake as analysis could then proceed on a data set of behaviours that could be reliably rated and readily observed by trained clinicians.

The second procedure used to reduce missing data was to substitute other trials. Because the test-retest data showed that there was excellent consistency between trials, there was good evidence that this was a reasonable approach to take. However, there were two factors that might have affected the use of this approach. First, when children refused all examiner administered trials, mothers were asked to administer the SOMA. Where possible they were instructed in how to administer the food/liquid. However, they sometimes did not administer it correctly and the child may have been given undue assistance. Second, some children would only self-feed and the administration of the SOMA could not therefore be controlled. This resulted in some items being non-rateable because the standardised administration was affected. This occurred in very few cases and was therefore not considered to have had a major effect on the data.

The final procedure outlined was that developed for the children with cerebral palsy. For some children a decision was made not to administer a further trial or to omit the OMC category altogether where there were overt oral and/or pharyngeal difficulties. For example, some children choked or exhibited difficulties in dealing with the texture and others were considered at risk for aspirating the food/liquid in question. Because the SOMA was being administered in the home there was not always access to suction equipment. Although the author is trained in emergency procedures, some children had such obvious difficulties that it was not considered safe to proceed any further. As a result such trials were coded as failed, reflecting the severity of

the oral motor impairment in this group of children.

Establishing the normal/abnormal status of each DOM behaviour

Because there was limited information available from previous literature about both normal oral motor skill development and abnormal oral motor behaviour, it was important to establish a rigorous procedure for defining abnormality. In chapter 4 (The development study) a number of possible approaches were highlighted and discussed. Decisions about the status of a behaviour were not made until after all the video tapes had been rated. At the time of rating, each behaviour was simply classified as present or absent. This proved to be crucial as there were certain behaviours (eg: tongue protrusion) that were described in the literature as being abnormal (eg: Morris and Klein 1987) yet were found to occur commonly in the comparison group, suggesting that in fact the presence of such a behaviour alone was not a sign of abnormality. Decisions as to the status of each behaviour were made therefore on the basis of the modal response of the comparison group (n=56), normative data were used wherever available and if necessary clinical judgment. There were no DOM behaviours that could not be classified in this manner.

If decisions as to the normal/abnormal status of each behaviour had been made prior to rating the tapes the results may have been different. This can be clearly illustrated again by considering the DOM behaviour 'tongue protrusion'. Tongue protrusion was rated in some detail in the SOMA; this rating was based not only on the presence or absence of the behaviour, but

the frequency with which it occurred and the degree to which the tongue was protruded (see Tables 3 and 6, Tongue 10 to Tongue 14 in Reilly et al 1995 in appendix 1). In the analysis, the frequency and degree of protrusion were found to be far more discriminating than just the presence or absence of the behaviour (See screening indices for the OMC categories purée, solids, cracker, trainer cup and cup in Chapter 4 The Development Study). A parallel can be drawn between the stereotypic and repetitive hand movements characteristic of some children with autism. These movements are present during normal development and are seen in many children who do not have autism. However, the determining factor in defining such abnormality is the frequency and degree with which they occur rather than just the presence or absence of a behaviour. Similarly, in the development of some oral motor skills the presence or absence of the behaviour alone should not determine abnormality as has been illustrated by the DOM behaviour tongue protrusion.

Ideally, the SOMA should now be administered to a large sample of normally developing infants (aged between 6 and 24 months). This would provide researchers and clinicians with normative data and add much to our knowledge of how oral motor skills emerge during infancy and early childhood.

Inter-rater and test-retest reliability

Reliability was calculated in two separate steps. This approach was novel and has not to my knowledge been previously undertaken in a study of oral

motor functioning. In other areas of child development however, inter-rater reliability has been undertaken in two stages. McConachie and Mitchell (1985) describe the reliability of the coding system they developed for rating interactions between parents and their mentally handicapped children. They calculated reliability in 2 linked stages; first, the presence/absence of the actual communication acts was rated, followed by the actual coding of the acts.

The first step in determining the reliability of the SOMA was to ascertain the agreement between two independent raters as to the rateability of each behaviour; inter-rater reliability. Both rateable and non-rateable items were described in chapter 3 (see Reliability, inter-rater and test-retest). The non-rateable category was necessary to incorporate behaviours that were refused, omitted or not easily observed, in other words, whether two independent raters agreed that they could in fact rate each behaviour. .

The second step in establishing the inter-rater reliability of the SOMA was to compute reliabilities on the rateable behaviours, that is, whether two raters agreed the behaviours were present or absent. Step one was vital as the study was undertaken in the children's homes, occasionally in less than ideal situations, with mothers filming the SOMA assessments. It would have been of limited value to proceed with the validation of the instrument if independent raters could not at this stage agree which behaviours were rateable. An example can be found by studying the DOM behaviour 'tongue tip elevation'

(see table 3 and table 6 - tongue 3). Either the two independent raters could not agree as to the 'rateability' of this behaviour (stage 1) or there were too few rateable behaviours to calculate a kappa (stage 2).

The degree of reliability was measured by the kappa coefficient. Other methods of calculating inter-rater and test-retest reliability such as percentage agreement and the correlation coefficient are sometimes used, however, they have been shown to give less than ideal results and ignore the degree of agreement that can be obtained by chance (Bland and Altman 1986, Fleiss 1981). Landis and Koch (1977) and Nunnally (1978) both give some guidance as to acceptable levels of reliability. Nunnally (1978) states that for exploratory studies modest reliabilities (a kappa value of 0.7) are sufficient and suggests that for many basic research studies it is not worth seeking reliabilities beyond 0.8. However, where more critical decisions are involved, such as those that might affect the treatment offered to individuals, then reliabilities of 0.9 are necessary. Because this was not the case with the SOMA, modest reliabilities greater than 0.7 were considered adequate and the guidelines suggested by Landis and Koch (1977) adopted. Kappa values greater than 0.75 were considered to represent excellent agreement beyond chance whereas those below 0.40 were taken to represent poor agreement beyond chance and those between 0.40 and 0.75 represented fair to good agreement (Landis and Koch 1977).

The inter-rater reliabilities obtained for both the rateability of each behaviour

and the presence and absence of DOM behaviours were excellent. In deciding whether a behaviour could be rated or not, perfect agreement was obtained for 72% of DOM behaviours (the mean percentage agreement averaged for all 7 OMC categories). The kappa value for 20% of the DOM behaviours was greater than 0.75, in 10% it was between 0.40 and 0.75. Only 2% of DOM behaviours obtained poor reliability, that is, kappa values less than 0.40.

Similarly, 69% of the rateable DOM behaviours achieved perfect agreement, that is, the raters agreed that the DOM behaviour was either present or absent. Five per cent of the kappa values were greater than 0.75 and 25% were between 0.40 and 0.75. Only 7% were below 0.40 representing poor agreement beyond chance.

Test-retest data, over a substantive time period, were not collected for the SOMA. This was not feasible within the constraints of the study. Instead the consistency between the first and third trials were compared. The results were excellent, showing that perfect agreement was obtained for 84% of the DOM behaviours (mean percentage agreement across all seven OMC categories). Six per cent of the DOM behaviours were greater then 0.75 representing excellent agreement beyond chance, and 9% were between 0.40 and 0.75 (fair to good agreement). Poor agreement was achieved for less then 1% of the DOM behaviours (<0.40).

The reliability data collected and analysed for the SOMA is the largest reliability study undertaken on oral motor skills in young children. Apart from the Multidisciplinary Dysphagia Profile developed by Kenny and his colleagues (1989), which was shown to have good reliability, almost no studies have produced rigorous reliability data. For the development of the SOMA any behaviours with poor reliability (kappa less then 0.4) were not included in the final analysis. Interestingly Kenny et al (1989) continued to include some items where the reliability ratings were poor as they felt they were of clinical significance.

The inter-rater and test-retest data presented were determined on a subset of 10 infants, who each took part in 3 trials rated by two therapists. The reliability of an instrument varies according to the population on whom that instrument is being assessed. The figures presented in Reilly et al (1995) in appendix 1 (tables 3 to 10) are applicable only to a sample of non-neurologically impaired infants (children with non-organic failure to thrive and children with normally developing oral motor skills were included). However, equivalent reliability studies on children with Down's syndrome were made separately and very similar findings were obtained (Spender et al 1995a, Spender et al 1995b). Some structured clinical evaluation schemes (Morris 1982, Stratton 1981, Gisel and Patrick 1988) include DOM behaviours that we have identified as not reliably rateable, particularly, tongue movements and swallowing. These behaviours are repeatedly mentioned in the literature as being problematic in children with OMD but the value of including such DOM behaviours in a

clinical evaluation when they cannot be easily observed or reliably rated must be questioned.

Inter-rater and test-retest reliability should now be established on a sample of children with cerebral palsy. Motor performance is thought to vary in children with cerebral palsy, both from day to day and even during the same 24 hour period. Blair and Stanley (1985) attempted to establish some reliability data when they asked different groups of professionals to categorise children with cerebral palsy according to the distribution and type of motor disorder present. The results showed that there was considerable variability both between and within observers as to the diagnosis. However, Kenny et al (1989) were able to show that it is possible to establish acceptable levels of inter-rater reliability on the oral motor skills of children with cerebral palsy.

Research hypotheses:

Three major hypotheses were proposed in the thesis. Each will be discussed in turn.

<u>Discrimination between the comparisons and children with cerebral palsy</u>

- It was hypothesised that the SOMA would be a sensitive instrument capable of identifying children with OMD associated with cerebral palsy and discriminate them from children with normal oral motor skills.

The method of analysis chosen was novel and termed a 'seeded cluster analysis because the children with cerebral palsy were to act as 'seeds'. In both the development study and the validation study the results of the cluster analysis discriminated the 'seeds' or children with cerebral palsy from the comparison subjects for the majority of OMC categories. That is, clusters designated as 'normal' contained comparison subjects and those designated as 'abnormal', the 'seeds' or children with known pathology.

OMC categories

Some OMC categories (eg: the foodstuffs purée, semi-solids, solids and cracker) provided better discrimination than others (eg: liquids - trainer-cup and cup). The OMC category purée proved to be an excellent category for discriminating the comparison subjects from the children with CP. Whereas only 9% of the comparison subjects appeared in the abnormal clusters for both samples, 92% of the CP children appeared in abnormal clusters for sample 1 and 100% in sample 2. Apart from the OMC category - cracker, very few comparison children (10% or less) belonged to the abnormal amalgamated clusters whereas the proportion of children with CP that were members of abnormal clusters ranged from 54% (cracker - sample 1) to 100% (purée sample 2).

For each of the seven OMC categories the children with CP achieved higher scores than both the NOFT children and the comparison subjects. Their mean scores were significantly different for all OMC categories (purée, semi-solids,

solids, cracker and bottle), with the exception of trainer-cup and cup. These findings indicate that the SOMA was able to identify children with CP and discriminate them from children with normal oral motor function. It is interesting that the OMC category liquids (trainer-cup and cup) did not produce the same level of discrimination.

Two possible explanations for this finding could be proposed. The first and most obvious explanation could be that children with CP do not have difficulty managing liquids. However, clinical experience and videofluroscopic studies have shown, that individuals with CP have the most serious difficulties managing liquids as they are unable to form a bolus in preparation for swallowing (Griggs et al 1989, Morton et al 1993). As a result the liquid spills anteriorly causing excessive liquid loss or posteriorly resulting in premature overspill into the pharynx before a swallow is triggered. Subsequently such children run a much higher risk of aspirating when drinking.

A second, and more likely explanation, is that attempting to assess drinking solely by observational means is inadequate. Unless children exhibit overt signs of oral and or pharyngeal dysfunction (eg: coughing and choking) it may not be detected. Further support is given to this theory by the recent findings suggesting that the cough reflex may be suppressed in many children with severe CP who have associated pulmonary damage as a result of frequent and prolonged bouts of aspiration (Stallings et al 1993). Furthermore, many children with CP known to aspirate, do so silently, often with no signs that

they are experiencing difficulty (Griggs et al 1989).

The fact that purée and solids provided better discrimination (that is, between the children with CP and the comparison subjects) than did semi-solids and cracker was of interest both clinically and in research. Whilst the proportion of children with CP appearing in abnormal clusters for cracker was low (54% - sample one and 69% - sample two), the number of comparison children in abnormal clusters was relatively high (17% were in the abnormal clusters for both sample one and two). The finding could be explained in part by the fact that children with CP tend to cope better with a firm texture; clinical evidence suggests that these foodstuffs provide the child with increased sensory feedback and enable them to form a more cohesive bolus in preparation for swallowing. However, it does not explain why the proportion of comparison children appearing in abnormal clusters was so high. Both developmental and experiential elements could be involved. For example, comparison children that failed the DOM behaviours for cracker might not have had prior experience in managing this texture. Alternatively in the age group tested the skills required might not be fully developed. Further investigation of these factors should be possible when normative data become available.

Comparing the samples

The results obtained from the cluster analysis on both sample one and two were remarkably consistent for all but one OMC category. The exception was bottle drinking, where 92% of the children with CP were members of abnormal

clusters in sample one whereas only 62% belonged to abnormal clusters in sample two. The reason for this difference is not clear. Future studies of larger samples of children with CP may provide an answer.

In summary, five of the seven OMC categories of the SOMA provided excellent discrimination between children with CP and the comparison subjects. The results for both sample one and two were remarkably consistent. The OMC categories that presented purée or solids textures, provided far better discrimination than the liquids.

Discrimination between failure to thrive, cerebral palsy and comparison children

- Second, it was hypothesised that the SOMA would identify a proportion of children with non-organic failure to thrive as having OMD and discriminate them from the comparison children and the children with cerebral palsy.

The proportion of children with NOFT that appeared in the amalgamated abnormal clusters for each OMC category ranged from 5% to 45% in sample one (mean proportion 25%), and from 5% to 45% for sample two (mean proportion 21%). In contrast, far fewer comparison children appeared in

abnormal clusters, between 7 and 17% for both sample one and two (mean proportion 11%).

It was expected that a proportion of children with NOFT would have OMD but that it would not be as severe as that seen in the children with CP. Surprisingly, the oral motor profiles of the 2 groups were not remarkably different. For the majority of OMC categories (solids and cracker - both sample one and two, semi-solids - sample two only) the abnormality scores obtained by the children with FTT were not significantly different from the children with CP. The exception was the OMC category purée where the abnormality scores of the children with FTT were significantly different from those with CP. For some OMC categories the abnormality scores of the children with FTT were actually higher than those obtained by the children with CP.

Two OMC categories (purée and semi-solids) discriminated the children with NOFT from the comparison subjects. For the remaining categories there were no significant differences between two groups, although the children with NOFT consistently achieved higher abnormality scores.

These findings suggest that the characteristics of the OMD seen in a proportion of children with NOFT were similar to that observed in children with CP. Although OMD is recognised as being associated with CP, the same cannot be said for children with NOFT. Very few studies (Mathisen et al 1989,

Ramsey et al 1993) have explored the notion that some children with NOFT might indeed have a specific underlying organic deficit affecting their ability to ingest food. This finding adds weight to the notion that children previously classified as having NOFT, may have a subtle unidentified, neurological deficit and the term 'non-organic' maybe inappropriate for such children.

The sensitivity of texture in predicting abnormality

- Third it was hypothesised that some of the textures used in the SOMA would be more discriminating than others in identifying abnormality. Furthermore, children with cerebral palsy would perform poorly on all textures whereas those with non-organic failure to thrive would have textural specific OMD.

It has already been ascertained that certain OMC categories were more discriminating than others in predicting group membership and that there was good consistency between sample one and two. Although children with CP were shown to have consistently higher scores for all OMC categories, they did not perform poorly on all OMC categories; in general, liquids provided less good discrimination. Possible reasons for this were discussed earlier in this chapter. The children with NOFT were found to have texture specific OMD (purée and semi-solids) although their profiles were not dissimilar to those

children with CP. The children with CP were not observed to have difficulties with liquids. Clinical and radiological evidence suggests that this is not the case and the observational methods used were not sufficiently sensitive to detect the underlying problems.

Unlike the OMC categories trainer-cup and cup, bottle was found to be a good predictor of OMD in children with CP. Although this appears a somewhat surprising finding there are possible explanations. When drinking from the bottle most children with cerebral palsy had obvious difficulties initiating a suck - swallow response, which was easily observed, and were unable satisfactorily to extract any liquid. In contrast, when drinking from a trainer cup, the child's motor impairment prohibited him/her from self-feeding and the liquid was presented by the examiner. In order to ensure that many of the children received a drink some liquid had to be tipped into the child's mouth. In retrospect, it was extremely difficult to administer this in a standard manner. Some of the children were at risk of aspiration of food and liquids and were perhaps therefore fed more cautiously. In addition, some of the behaviours that would be used to judge normal and abnormal behaviour during drinking could not be reliably rated, in particular the swallowing behaviours. The results add support to the contention discussed earlier that a child's ability to swallow and manage liquids, cannot be assessed by observation alone.

Children with CP tended to do better with an increase in texture, with the exception of solids. Gisel (1992) suggested that one of the most

discriminating textures for identifying abnormality in children was purée rather than more solid textures. the results obtained in this thesis support this suggestion. One explanation could be that they find a more solid cohesive bolus easier to manipulate than a purée which tends to spread around the oral cavity.

In summary, almost all the children with CP performed poorly on five of the seven OMC categories whereas a proportion of children with NOFT had texture specific dysfunction observed for just two OMC categories. However, they did tend to obtain consistently higher abnormality scores than the comparison children for most of the remaining OMC categories.

Further validation procedures - The screening version of SOMA

Comparison of the effectiveness of the different screening instruments developed

The following table, reproduced from chapter 5 - The Validation Study, illustrates the derivation of the different indices developed. Each index will be discussed in turn.

Sample 1		Sample 2	
Index	**Derivation**	**Index**	**Derivation**
1a	behaviours which discriminate the 2 most abnormal clusters from all others	2a	behaviours which discriminate the 2 most abnormal clusters from all others
1b	behaviours which discriminate the most abnormal cluster from all others	2b	behaviours which discriminate the most abnormal cluster from all others
1c	combined index (1a + 1b)	2c	combined index (2a + 2b)
1d	switching indices (2a run on sample one)	2d	switching indices (1a run on sample two)
1e	combined index (1a + 2a)	2e	combined index (2a + 1a)

Index 1a and index 2a

The first screening version of SOMA was developed using a restricted subset of behaviours that tended to discriminate between children with normal and abnormal oral motor skills as defined by their association with overt

neurological handicap. This subset of oral motor behaviours was highly effective in discriminating children who, the series of cluster analyses suggested, had abnormal oral-motor skills from others. Decisions were not made about the functional integrity, efficiency or developmental appropriateness of individual children's oral-motor skills. The validation was based on a series of comparisons with children who had CP, chosen because they had grossly abnormal oral-motor skills. The technique developed was designed to move the validation process of this screening instrument beyond the use of global clinical impressions, to a sophisticated combination of applied clinical skills and statistical analysis of DOM behaviours.

In stage one (The Development Study) with the exception of semi-solids (PPV 76%), the positive predictive value of the scoring procedure was greater than 85% (tables 33 to 39 in chapter V). The sensitivity of the screening instrument, that is, the proportion of true cases identified, was equal to or greater than 85% and the specificity of the instrument for all OMC categories was found to be greater then 95%. Because the efficiency of the screening procedure was evaluated on the same sample from which the original abnormal groups were identified it was therefore expected that the procedure would show a lower degree of efficiency on an independent sample of children.

Therefore it was necessary to establish whether the screening version of the SOMA could accurately differentiate between other independent groups of

children with and without OMD. When the same procedures were repeated in the validation study using an independent sample of children with cerebral palsy, equally good results were obtained. The positive predictive values were greater then 87% for all OMC categories, the sensitivity was greater than 87% and specificity ratings greater than 95%.

Deciding on acceptable rates for diagnostic certainty depend to an extent on the disease or condition under test and the available treatment regimes (Sackett et al 1991). It is necessary to consider the consequences of misdiagnosing patients; for example, whether considerable harm could be done if cases were missed. Could the consequences be life threatening? Alternatively, what are the consequences of over-diagnosing, that is, falsely identifying non-cases as cases? There are two possible ways to look at this problem. First, if the sensitivity of the test is poor (that is the number of true cases with positive tests is low), then significant harm may be done by missing true cases and therefore not initiating the appropriate treatment. This would be particularly important if the condition in question were life threatening. Second, if the specificity of the test is poor (that is, many non-cases screen positive), significant harm could also be done by over diagnosing. In such situations, unnecessary anxiety may be raised by labelling non-cases as cases.

If the specificity of the screening version of the SOMA had been poor, identifying children as having OMD when in fact they did not, then the

consequences would not be as serious as in patients with life threatening conditions. In other words, little harm could be done by over diagnosing. The management of the condition would only occasionally involve further tests of an invasive nature or expensive treatments. However, if the sensitivity of the test was low, with failure to identify true cases, the results could significantly affect a child's health and delay necessary treatment.

The number of true cases missed using the SOMA was very low, with the exception of the OMC category - semi-solids (sample one only). Ideally the SOMA should not be administered in isolation; instead it was designed to be used as part of a battery of tests investigating a child's ability to ingest food and liquid orally. The results should therefore be incorporated with those obtained from assessments such as pH monitoring and videofluroscopic studies of swallowing.

To summarise, the PPV, sensitivity and specificity rates calculated for both sample one and sample two were excellent making it an accurate diagnostic tool capable of identifying children with OMD and discriminating them from those with normal oral motor function.

Alternative screening procedures

A number of alternative screening indices were developed and their efficiency explored.

Index 1b and index 2b

Index 1a and 2a (discussed earlier in this chapter) were formed from the behaviours that discriminated the 2 most abnormal clusters from all others. However, there were a number of behaviours that were failed only by members of the most abnormal cluster. It was interesting to explore then whether an index formed from the behaviours that discriminated subjects in the most abnormal cluster from all others, would be efficient. Results of the sensitivity, specificity and positive predictive values indicated that this index had limited value. By manipulating the cutoff points it was possible to raise the PPV and specificity of the index at the expense of lowering the sensitivity, resulting in very few true cases (46%) achieving a screen positive score. The problem was that this index identified only a small proportion of children with oral motor deficits. There was a high number of false positives, that is, children scoring below the threshold (a normal score) yet belonging to abnormal clusters. It was concluded that it would not be of use as a screening index. However, the actual DOM behaviours that formed this index might well be of interest clinically, particularly in planning oral motor treatment.

Index 1c and index 2c

The possibility of combining index b (formed from the DOM behaviours that discriminated the most abnormal from the normal clusters) and index a (formed from the DOM behaviours that discriminated the two most abnormal clusters from the normal clusters) for both sample one and two was considered. The PPV, sensitivity and specificity values obtained by using

index were excellent. However, the number of oral motor behaviours forming the screening index increased and the assessment was more time consuming to both administer and score. Further development of this index was not therefore pursued.

Two further developments of interest were undertaken.

Index 1d and index 2d

The first involved applying each index to the opposite sample. In other words the index generated on sample 1 (index 1a) was applied to sample 2 and index 2a (generated on sample 2) was applied to sample 1. This was felt to be of particular interest where the DOM behaviours that formed the indices for the different OMC categories differed as was the case for solids and bottle. For the remaining OMC categories the indices were very similar with many DOM behaviours common to both indices. The results obtained were excellent, even for bottle and solids where the DOM behaviours differed most markedly.

To summarise, switching the indices from the sample on which they were generated to an independent sample of children with cerebral palsy, resulted in equally good discrimination, with only a few minor variations. The consistency of the results obtained was remarkable.

Index 1e and index 2e

The final development was to combine the index generated on sample one (index 1a formed from the behaviours that discriminated the two most abnormal clusters from others) to that generated on sample 2 (index 2a also formed from the behaviours that discriminated the two most abnormal clusters from others - sample two). It has already been shown that both these indices were sensitive in detecting children with known oral motor deficits and for most OMC categories contained a similar set of behaviours. Furthermore, when each was swapped and run on the opposite sample from that which they were generated on, equally good discrimination was found. However, the DOM behaviours that formed the indices for two of the OMC categories (solids and bottle) differed and it was therefore necessary to form a definitive list of behaviours that would form the final index for each OMC category. Therefore the two indices were combined and each was applied independently to each sample in turn.

The results showed that the combined index was the most efficient index for all OMC categories. The positive predictive value, sensitivity and specificity of each index was either the same or greater than those values originally obtained. This final index is the recommended screening version of the SOMA.

Methodological issues

When developing a diagnostic test there are a number of methodological issues which need to be considered. Sackett et al (1991) proposed eight guidelines for deciding on the clinical usefulness of a diagnostic test. Two of these were discussed earlier in this chapter; the reproducibility of the test result (inter-rater and test-retest reliability) and the definition of the term 'normal' as applied to the population studied. The remaining guidelines proposed by Sackett et al (1991) now require consideration.

Of major importance in the development of any diagnostic test is whether there has been any comparison with the 'gold standard' , that is an accepted reference test (Sackett et al 1991). Whilst comparing the SOMA to a 'gold standard' would have been desirable, none actually existed. In fact the lack of an appropriate diagnostic tool for the age range and children studied was the primary reason for developing the SOMA. Sackett et al (1991) suggests that when there is no 'gold standard' an alternative is to simply ask whether the patient is better off as a result of undergoing it. For both the children with CP and NOFT the conclusion is that indeed they are better off for a number of reasons. First, children with NOFT were for the first time identified as having an organic component which could account at least in part for their severe growth failure. Second, identification of the OMD affects the type of intervention undertaken with the child and family and most importantly alerts professionals to the possibility of it being present in a proportion of children

with NOFT. Third, appropriate intervention with children who have OMD which is affecting the ingestion of sufficient nutrients can reverse the growth failure and have a profound effect on the families attitude to the presenting problem.

For the children with CP identification of the exact nature of their oral motor deficits is beneficial. The severity of the OMD (that is for all textures) in association with other clinical signs, for example, severe growth failure, pharyngeal dysphagia and lung damage, all indicate that the child in question might have serious difficulty achieving a safe and satisfactory oral intake and might therefore require feeding via non-oral means. In the long term this may necessitate surgical intervention. Alternatively, some children with CP have more pronounced dysfunction with specific textures and therefore with texture manipulation might not require such aggressive intervention (Gisel 1992). Determining the exact nature and severity of the OMD has become an important component in determining the method by which children with CP will be fed. Until the development of the SOMA, speech and language therapists had no reliable and valid diagnostic tool to assist them in making these crucial decisions. Instead they relied on clinical experience and global descriptions of a child's behaviour.

The SOMA was evaluated on two independent but small samples of children with CP, all with severe OMD. Currently in progress is a study of a community sample of children including an appropriate range of mild, moderate and

severe OMD. The SOMA has not yet been used to evaluate the effectiveness of different forms of treatment. For example, anecdotal reports suggest that an improvement in oral feeding sometimes accompanies improved nutritional state in children with CP. Theoretically the SOMA could be used to evaluate the efficacy of such observations. Similarly, little evidence exists to suggest that oral sensorimotor treatment has a significant effect on oral motor skills. The SOMA could be used to evaluate a variety of treatment methods. It will be interesting to ascertain if it is sensitive enough to detect the subtle changes that might occur as a result of treatment.

The SOMA was designed to be used as part of a battery of tests (for example, videofluroscopy and pH monitoring) to detect dysphagia in young children. Because the problems that present are often complex and the causes multifactorial, no individual diagnostic test will be sufficient. To date, the SOMA has not been compared with other methods of detecting dysphagia. From the results presented it is clear that in order to detect swallowing difficulties, it is necessary to combine the SOMA with the videofluroscopy procedure.

The SOMA has been described in detail; administration and scoring manuals exist. The scoring system is simple and can now be adopted by any trained speech and language therapist (or related health professional) with experience of young children with dysphagia.

Conclusions:

The Schedule for Oral Motor Assessment (SOMA) is an instrument which can be administered relatively simply by a trained observer, such as a speech and language therapist. It has been designed to detect subtle degrees of oral-motor dysfunction in young infants. Preliminary enquiries revealed that there was little consensus among clinicians about what developmentally appropriate skills would be observed in children between 12 and 18 months of age. There was even less agreement about what patterns of deficiencies in skills would indicate significant oral-motor dysfunction.

The discriminant validity of the SOMA was established by means of novel statistical procedures whereby children who had confirmed grossly deficient oral-motor skills, in association with cerebral palsy, were entered into a cluster analysis together with a large number of apparently normal subjects, a substantial minority of whom were nevertheless thought to be at risk. Two independent samples of children with cerebral palsy, matched as closely as possible on a number of variables thought to be significant were used. A number of different methods by which criterion validity was established with this sample were undertaken. The validation procedures undertaken on both samples produced remarkably consistent results.

A screening version of the instrument was developed and subjected to rigorous testing on both samples. The abbreviated list of oral-motor behaviours that form the final indices for each OMC category should direct

clinicians towards specific skills that could be used for screening purposes, when faced with a preverbal child who is suspected of having oral-motor difficulties. The OMC categories involving more solid foodstuffs were more sensitive than liquids in discriminating children with oral motor dysfunction from those with normal oral motor skills.

The screening instrument could be applied to a wide range of ages, from those who have just been introduced to mixed feeds (minimum age of 6 months) to those who are totally independent feeders with a maximum appropriate age in normal children of about 2 years. In children who are developmentally delayed the upper age limit is determined largely by the extent of the subject's disability; the instrument should be perfectly suitable for assessing the oral-motor skills of children whose developmental abilities in general are equivalent to a chronological age of 6 months to 2 years.

Not all OMC categories would be applicable to children less than 12 months of age. Whilst the OMC categories purée semi-solids and liquids (bottle and trainer-cup) could be administered to children aged between 6 and 9 months, only anecdotal evidence and single case studies to suggest that infants in this age range could deal with more highly textured foodstuffs or manage drinking from a cup. Further study of this age range is necessary.

The screening version of the SOMA should be used in conjunction with a battery of tests designed to investigate oral, pharyngeal and oesophageal function in young children

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Chapter 7

Concluding chapter

Contents:

A. Limitations of thesis

1. Reliability study

1.1 Inter-rater reliability

In establishing the reliability of an instrument a number of different types of measures could be made. The first and most commonly referred to is the consistency among repeated observations of the same phenomenon. That is, is the measurement taken generalisable? It can be tested in two ways; first, the inter-rater reliability (that is, do two raters, agree as to each others ratings) or the inter-tester reliability (between observer agreement)

Inter-rater reliability (both stage 1 and stage 2) data is given in the main body of the thesis and was calculated using the kappa statistic. That is, two raters (blind to case status) rated the same behaviours and the agreement expected beyond chance was calculated.

Ten subjects, (three trials from each subject) resulted in a total of 30 pairs of ratings. However, because the three trials from the same subject were included, it is possible that the inter-rater reliability values reported in the thesis might well have been inflated because of this approach. In retrospect it would have been preferable to use 30 subjects, that is, 30 independent ratings, thus rating only one trial from each subject.

Because of this measures of within and between rater reliability were undertaken. The intraclass correlation coefficient, which is a useful method for determining if there is a relationship between and within two sets of data, was

chosen. In the case of the two sets of ratings in this study it assesses whether the data from rater one has something in common which is different from that of rater two. If measures are equal within each group, then error MS = 0, and $r = 1$. If there is more variability within groups than there is between groups, then r will be negative.

Only the first trial of data from 10 subjects was used in the study The results obtained were in the main highly significant for the DOM behaviours that formed each index for each OMC category, suggesting that there was in fact very little variability either between or within groups. In tables 1 to 7 the behaviours that form each screening index are shown and the correlation coefficient computed for each behaviour.

Table 1. Intraclass correlation coefficients for the OMC category purée		
DOM behaviours	**Intraclass correlations**	**p level ***
React 1	r =.60	*
Sequencing 1	r = 1.0	**
Lip 1	r = 1.0	**
Lip 2	r = .99	**
Lip 3	r = .73	**
Lip 11	r = .99	**
Tongue 10	r = .99	**
Tongue 11	r = .99	**
Jaw 1	r = .74	**

* $p < 0.005$
** $p < 0.001$

Table 2. Intraclass correlation coefficients for the OMC category semi-solids		
DOM behaviours	**Intraclass correlations**	**p level ***
Drool 1	r =.99	*
Sequencing 1	r =.99	**
Initiation 1	r = .90	**
Lip 13	r = .70	**
Jaw 1	r = 1.0	**
Jaw 2	r = .59	**
Jaw 3	r = 1.0	**
Jaw 10	r = 1.0	**

* $p < 0.005$
** $p < 0.001$

Table 3. Intraclass correlation coefficients for the OMC category solids		
DOM behaviours	**Intraclass correlations**	**p level ***
Food loss 1	*r* =1.0	***
Drool 1	r = .99	***
Sequencing 1	*r* =.73	***
Lip 1	*r* = .74	***
Lip 2	*r* = .73	***
Lip 4	*r* = 1.0	***
Lip 11	*r* = .75	***
Tongue 10	*r* = .41	*
Jaw 1	*r* = .75	***

* p < 0.01
** p < 0.005
*** p< 0.001

Table 4: Intraclass correlation coefficients for OMC cracker		
DOM behaviours	**Intraclass correlations**	**p level**
Food loss 1	*r* =.79	**
Drool 1	*r* = .99	**
Initiation 1	*r* = .99	**
Lip4	*r* = 1.0	**
Lip7	*r* = 1.0	**
Lip 9	*r* = 1.0	**
Tongue 10	*r* = .73	**
Tongue 11	*r* = .72	**
Tongue 12	*r* = 1.0	**
Tongue 13	*r* = .72	**
Jaw 2	*r* = 1.0	**
Jaw 3	*r* = .89	**
Jaw 4	*r* = .89	**
Jaw 5	*r* = 1.0	**
Jaw 8	*r* = 1.0	**
Jaw 9	*r* = 1.0	**
Jaw 11	*r* = .78	**
Jaw12	*r* = .78	**
Swal 9	*r* = .79	**
Bite 5	*r* = .99	**
Bite 8	*r* = 1.0	**
Bite 12	*r* = 1.0	**

** p< 0.001

Table 5: Intraclass correlation coefficients for OMC bottle		
DOM behaviours	**Intraclass correlations**	**p level**
React 2	*r* = 1.0	**
React 4	*r* = 1.0	**
Accept 2	*r* = 1.0	**
Lip 3	*r* = 1.0	**
Lip 5	*r* = 1.0	**
Lip 6	*r* = 1.0	**
Lip 7	*r* = 1.0	**
Jaw 1	*r* = 1.0	**
Sequencing 1	*r* = 1.0	**

** p< 0.001

Table 6: Intraclass correlation coefficients for OMC T-cup		
DOM behaviours	**Intraclass correlations**	**p level**
Liquid loss	$r = 1.0$	**
sequencing 2	$r = 1.0$	**
sequencing 3	$r = 1.0$	**
Tongue 10	$r = 1.0$	**
Tongue 11	$r = 1.0$	**
Jaw 1	$r = 1.0$	**
Jaw 6	$r = .99$	**
Jaw 10	$r = 1.0$	**
Jaw 12	$r = 1.0$	**
Swallow 1	$r = 1.0$	**
Swallow 4	$r = 1.0$	**
Swallow 5	$r = 1.0$	**
Swallow 6	r = .99	**
Swallow 7	r= .99	**

** p< 0.001

Table 7: Intraclass correlation coefficients for OMC cup		
DOM behaviours	**Intraclass correlations**	**p level**
Accept 2	$r = 1.0$	**
Sequencing 2	$r = 1.0$	**
Sequencing 3	$r = 1.0$	**
Liquid loss	$r = 1.0$	**
Tongue 10	$r = 1.0$	**
Tongue 11	$r = 1.0$	**
Jaw 1	$r = 1.0$	**
Jaw 4	$r = 1.0$	**
Swallow 9	$r = 1.0$	**

** p< 0.001

The SOMA has been the subject of a number of other reliability studies. Spender et al (1995) and Spender et al (in press) conducted inter-rater and test-retest reliability studies on children with Down's syndrome (DS). The first compared children with DS and their twin siblings and the second, children with DS and a comparison group matched for developmental age. The studies were carried out in an identical manner and equally good reliabilities were obtained. For example, perfect agreement (that is, kappa = 1.0) were achieved for 59% of the ratings, 37% exceeded 0.70 and only 4% (17 out of 407) were less than 0.4.

Finally, the inter and intra-rater reliability of the each screening instrument was

undertaken using the intraclass correlation coefficient. The results (for each screening instrument and each OMC category) are shown in table 8.

Table 8: Intraclass correlation coefficient for each screening instrument and each of the seven OMC categories.

Purée	Semi-solids	Solids	Cracker	Bottle	T-cup	Cup
$r = .94$ p=0.000	$r = .79$ p=0.000	$r = .71$ p=0.000	$r = .79$ p=0.000	$r = .91$ p=0.000	$r = .97$ p=0.000	$r = .88$ p=0.000

1.2 Test-retest reliability

Test retest reliability asks if the measurement taken is repeatable over time. Usually ratings are taken on 2 separate occasions and rated by the same observer. True test-retest was not undertaken because of the constraints of the study and clearly needs to be undertaken in any future study.

Spender et al (1995) and Spender et al (in press) calculated test-retest reliability in the same manner as that described in the thesis. Interestingly, equally good consistency was obtained between trial 1 and trial 3 for both the children with DS and the matched comparison group. Seventy-eight per cent of the ratings reached perfect agreement (that is kappa=1.0), 20.4% were 0.70 and only 1.6% (4 out of 252) were less than 0.4. These results show that the performance of children with DS was as consistent as those with failure to thrive (FTT) or the comparison children with no overt OM difficulties.

It will be crucial to test if the performance of children with cerebral palsy (CP) will be as consistent as those previously reported. In the community study, reported

in the main body of the thesis (Reilly et al in press), preliminary evidence suggests that in fact there might be greater variability in the OM performance of children with CP than the comparisons or those with FTT. To take account of this possibility at least 5 examiner administered trials have been included in the administration of the SOMA to children with CP. If performance is inconsistent over the 5 trials then it will be necessary to develop a method for scoring the responses. Clearly, it would not be satisfactory to score an individuals 'best performance' as this would not necessarily reflect the level of difficulty the child is experiencing and the consequences for the child and carers could be serious. For example, the 'worst performance' may in fact reflect serious oral and pharyngeal dysfunction which can result in aspiration of food and liquids.

1.3 Internal consistency

Another type of reliability that could be measured on an instrument is the internal consistency of the measure. This was not reported in the thesis but has been subsequently undertaken. One of the most common methods is Cronbach's alpha which is based upon the average inter-item correlations for a particular test. A value above .8 or .85 is desirable.

In table 9 reliability estimates for each of the OMC category indices are given. Each of the behaviours that formed the index (index 1a) were entered into the analysis and Cronbach's alpha was calculated when each of the items was removed from the scale (Alpha if item deleted).

Table 9: Reliability estimates for each of the OMC category indices (Index 1a only)			
OMC category	**Number of items**	**Alpha**	**Standardised item alpha**
Purée	9	.860	.856
Semi-solids	8	.880	.886
Solids	9	.930	.929
Cracker	22	.982	.982

1.4 Summary

To summarise, the inter-rater reliabilities reported in the main body of the thesis could have been inflated because only 10 subjects but three trials from each subject were used to make a total of 30 pairs of ratings. In retrospect it would have been preferable to compare ratings from 30 subjects. Because of this intraclass correlations were computed for the items that formed the screening index for each OMC category. In the main they were excellent indicating that there was in fact very little variability either between or within groups.

The test-retest reliability of the instrument has not been evaluated and it is crucial that this aspect of the instrument is evaluated in any future study. Any future reliability studies (either inter-rater, intra-rater or test-retest reliability) should include studies of children with CP.

2. Validation issues

2.1 Introduction

There are number of issues that need to be considered in the validation of any instrument. First, there is the question of face validity. As discussed throughout the thesis (see Chapter 6: Research aims) the methods adopted in assessing OM function were both appropriate and sensible. Second, there is the issue of content validity, or does the instrument reflect the whole or part of the dimension

being tested. The SOMA was designed to be used in conjunction with other instruments and will only assess part of the feeding process. Third, is the issue of criterion validity. That is, what external measures does the SOMA relate to?

There was no criterion or 'gold standard' by which the SOMA could be judged. This was in fact the major reason for developing the SOMA. It was important however, to consider what other measures, both of the child and family, might be associated with the main findings in the thesis. These issues will be discussed in two sections, the first entitled concurrent validity and the second, predictive validity.

2.2. Concurrent validity

In the thesis the findings of the cluster analysis were taken as the 'gold standard' for assessing how well the screening instrument of the SOMA discriminated between children with normal and abnormal OM function. The children with CP were expected to appear in abnormal clusters; they were after all chosen because of their feeding difficulties and it is well recognised that oral and pharyngeal dysfunction is associated with spastic quadriplegia. However, the appearance of a substantial number of children with FTT in abnormal clusters requires further discussion.

In the thesis the following hypotheses were generated about children with FTT:

- First, that a subgroup of children with FTT will have subtle, but clinically significant OM dysfunction of unknown aetiology.
- Second, the OMD in children with FTT will be 'textural specific', unlike children with CP who will perform poorly on all OMC categories.

Further hypotheses specific to the children with FTT and OMD are now proposed:

- That children with FTT and OMD will be 'biologically different' from children with FTT and 'normal OM function'.
- That OMD in children with FTT arises as a result of a subtle neurological disorder.
- That children with normal OM function, as identified by the SOMA, will come from more disadvantaged homes and experience poorer parenting styles than children with FTT and OMD.

SOMA screening instrument

The SOMA screening instruments for the OMC categories involving just the foodstuffs (purée, semi-solids, solids and cracker) were used. The OMC categories involving liquids were not included as they tended to be less sensitive in discriminating normal from abnormal oral motor behaviour. Furthermore, one of the main findings in the thesis was that liquids could not be reliably assessed solely by observational means (Reilly et al 1995).

Each child who scored above the threshold on the screening instrument for any OMC category was allocated a score of '1' indicating an abnormal OM score.

normal OM function. A total abnormality score, consisting of the summed score, across each of the first four OMC categories, was computed.

Sixty-three per cent of the FTT children (n=30) had abnormal scores on at least one OMC category (screening instruments). Seventeen subjects (57%) failed more than one OMC category. It was of interest to ascertain how subjects were distributed across the four OMC categories. No subject failed just the OMC category semi-solids, that is, all children who scored above the threshold on this OMC category also failed at least one other OMC category. Only 20% of subjects failed just the OMC category solids and 17% failed only the OMC category cracker. In contrast 41% of the children failed the OMC category purée and no other OMC category. This finding can be partially explained by the fact that there were more children who failed purée than any other category. To summarise, more than half the children with FTT had abnormal scores on at least one OMC category and 57% of subjects with OMD failed more than one OMC category. The results suggest that for half the children with FTT, OMD was not in fact textural specific and their appearance in abnormal clusters was not random. Of interest were the 17 (36%) children who failed more than one OMC category as the characteristics of their OMD were most similar to the 'seeds' or children with CP (see Chapter 6 - page 209-212). Therefore, for the purposes of further analysis, children who failed more than one OMC category (n=17) were defined as having OMD and the remainder (n=30) as having normal OM function.

A number of questions were proposed:

- Are there psychosocial and demographic factors which differentiate the FTT children with significant OMD from those without OMD?
- Could the children with FTT and OMD be developmentally delayed rather than having a specific OM deficit?
- Are the children with OMD 'biologically different' from those without OMD?
- Are there environmental factors that differentiate the groups?

Psychosocial factors and demographic factors

A range of psychosocial and demographic variables including factors such as, socioeconomic status (Osborn Social Index - Osborn and Morris 1979), a total adversity index, family size, social support, birth order, number of siblings, sex and race did not distinguish between children with OMD and those and with normal OM function. There was a trend for mothers of children with OMD to have lower scores on the 28 item General Health Questionnaire (Goldberg and Hillier 1979) and the Rosenberg Self Esteem Scale (Rosenberg 1965), however these results were not significant. The subscales of the GHQ measure somatic symptoms, anxiety, social dysfunction and severe depression. The two groups did not differ significantly on depression, anxiety or social dysfunction although there was a trend for mothers of children with normal OM function to have higher scores. The subscale 'somatic symptoms' did differentiate the groups; mothers of children with normal OM function scored significantly higher (x 6.5 SD: 4.0) than mothers of children with OMD (x 4.4 SD:2.1) ($p=0.04$). There were no group differences between either maternal IQ or maternal age.

Cognitive and motor development

In earlier reports Skuse et al (1992) showed that the children with FTT had significantly lower scores on both the Mental and Psychomotor Index of the Bayley Scales of Mental Development (Bayley 1969) as compared to the matched comparison group of children (Skuse et al 1992; Skuse et al 1994).

There was no significant correlation between the total SOMA abnormality score (or the abnormality scores for individual OMC categories) and the PDI (-.14 p=.33) or MDI (-.19 p=.19) of the Bayley Scales of Mental Development (Bayley 1969). The mean scores on both the Psychomotor (x 88.8 SD 18.7) and Mental Scales (x 87.6 SD 20.5) tended to be lower in children with OMD (n=17) than those without OMD (n=30) (PDI: x 101.1 SD: 14.9; MDI: x 104.2 SD 15.3), however the differences were not statistically significant.

Gisel (1992) suggested that the oral motor skills necessary to ingest puréed foodstuffs were the last to mature and in fact might not fully mature until well beyond 2 years (Gisel et al 1992). Twenty-two children (47%) with FTT were identified by the SOMA to have OMD on the OMC category purée and of these 13 (59%) also scored above the threshold for at least one other OMC category. This resulted in just 7 children who obtained an abnormal score for just the OMC category purée. Could the children that obtained an abnormal score for purée only (and not for any other OMC category) be developmentally delayed? This was not the case as those children with abnormality scores on purée only, had slightly higher MDI (x 113.5 SD 17.5) and PDI scores (x 100.5 SD 16.8) than those with abnormal scores on more than one OMC category (MDI: x 92.0 SD

19.9; PDI: x 92.3 SD 16.1). The differences were not statistically significant.

Anthropometry

There was a tendency for children with OMD to weigh less during the first 6 months ; weights were significantly different at 4 weeks and 6 months as can be seen in table 10. The total SOMA abnormality score was significantly correlated with weight in standardised scores at 3 months but not at any other time. There were no significant differences in the children's anthropometry at birth, although they tended to be shorter, have slightly smaller head circumferences and slightly lower birthweights.

Antenatal , perinatal and postnatal history

A perinatal and antenatal index of individual risk factors was computed and a risk score established for each subject (Skuse et al 1994). It included factors such as vaginal bleeding during pregnancy, infection, epilepsy, apgar scores and fetal distress. Although the children with OMD tended to also have higher prenatal and perinatal abnormality scores (x 27.71 SD 36.6) than children with no OMD (x 17.35 SD 25.2) this failed to reach statistical significance.

The Waldrop scale, a method of assessing minor physical anomalies in young children did correlate with the total SOMA abnormality scale (0.29; p=0.04) (Skuse et al 1994). The total possible anomaly score was 24. Children with OMD had significantly higher mean scores than those without OMD. The results are reported in Table 10.

In the course of the physical examination an assessment of neurological functioning and maturity was undertaken. This was based on the work of Touwen (1976) and Amiel Tilson and Grenier (1986). A composite score of gross motor skills was derived from 10 variables for which there was least missing data. Skills such as the ability to walk or sit unsupported, visual following, optical placing, reaction of hands were scored according to the weighting system recommended by Touwen (1976). Similarly a composite score for fine motor skills was also derived. The Gross motor function mean scores for the 2 groups differed slightly and the children with OMD tended to have higher abnormality scores although the differences were not statistically different. The mean score for both the fine and gross motor scales are shown in table 10.

Maternal reports of feeding difficulties

There was no significant correlation between maternal reports of early feeding difficulties, that is within the first 6 months, and the SOMA abnormality scores. This was a surprising finding as other studies have resulted in a strong correlation between maternal report of early feeding difficulties and current OMD in girls with Turner syndrome (Mathisen et al 1992). However, the data were collected retrospectively and involved asking the mothers to recall details of the child's early feeding difficulties. Furthermore, maternal perceptions of what constituted an early feeding problem varied markedly. For example, some mothers regarded a child who slept through the night from birth and did not demand to be fed as a 'good baby' whereas others thought this was problematic. Furthermore, some mothers attributed problems such as 'lack of milk' or 'nipple soreness' to the child whereas others clearly differentiated between maternal and

baby problems. For example, they described their babies as having a 'weak suck' or 'becoming fatigued'. Alternatively, one mother described her baby as a very difficult feeder. When questioned further she said the baby was 'a greedy pig' who was always hungry.

Table 10: Comparisons between children with and without OMD on a number antenatal, perinatal and postnatal variables .

	No OMD (n=30)**	OMD * (n=17)**	p level
Perinatal and Antenatal factors	***Mean (SD)***		
Birth length (SD scores)	.455 (.45)	-.249 (1.2)	ns
Head circumference (cm)	336.7 (11.3)	331.6 (13.3)	ns
Birthweight	-.687 (	-.877 (	ns
Ponderal Index	.22 (.03)	.25 (.04)	ns
Prenatal and perinatal score ***	17 (25.2)	27.7 (36.5)	ns
Gestation (weeks)	39.3 (1.95)	39.7 (1.2)	ns
Anthropometry †			
4 weeks	-.622	-.881	0.05
6 weeks	-.663	-.960	ns (0.06)
3 months	-.791	-1.14	ns (0.06)
6 months	-1.43	-1.60	0.04
9 months	-1.85	-1.96	ns
12 months	-2.04	-2.14	ns
15 months	-2.02	-2.14	ns
Weight/height	-1.63	-1.73	ns
Developmental assessment			
Gross motor scale ††	20.1 (4.4)	21.3 (3.9)	ns
Fine motor scale ††	7.0 (2.2)	7.8 (1.6)	ns
Waldrop scale †††	1.2 (1.1)	2.6 (2.9)	p =0.006

* Total SOMA abnormality score (summed score across 4 OMC categories)

** Numbers vary slightly for some variables due to a small amount of missing data

*** A prenatal, perinatal and antenatal scale of individual risk factors was computed and a risk score established for each subject.

† standardised weights for age from birth

†† Gross and fine motor scale compiled from Towen (1976) and Amiel Tilson and Grenier (1986)

†††Waldrop's scale is a method of assessing minor physical anomalies in young children (Waldrop et al 1968)

Maternal reports of current feeding problems also varied. Very few thought their child had any feeding difficulty. There was a tendency for them to attribute the child's behaviour to other causes. For example, the mother of one girl who excessively protruded her tongue and lost a considerable amount of food when eating described her child 'a dirty little girl'. A few said that their children were

'just too lazy to chew'. It was therefore extremely difficult to disentangle these findings and attempt to associate both maternal recall of early problems and current descriptions of feeding behaviour with the SOMA results.

Environmental measures

Measures were made of the home environment using the Home Observations for Measurement of the Environment (HOME) scales (Caldwell and Bradley 1984). It is designed to assess the quality of stimulation and support available to the child in the home environment. The infant version was used which comprises 45 binary choice items clustered into 6 subscales including; parental responsiveness, acceptance of the child, organisation of the environment, play materials, parental environment and variety of stimulation. There was little variation in the mean scores for both groups apart from the subscale acceptance (avoidance of restriction and punishment) where there was a statistically significant difference. Children with OMD had lower scores (x: 3.2 SD:2.5), indicating that there were less opportunities for exploring and playing than children without OMD (x: 5.2 SD: 1.5) (p=0.01).

Observational ratings of the cognitive growth fostering during mealtimes were rated using the subscale of Nursing Child Assessment Feeding Scale (NCAFS) scales developed by Barnard (1978). In table 11 the proportion of children from both groups who passed each item are shown.

The results suggest that there were subtle differences in the mealtime behaviour of mothers and children with FTT, however, they were not in the expected

direction. Although in both groups there was a striking lack of verbal interaction, a finding described earlier by Skuse et al (1992), there was a tendency for mothers of children with OMD to be less responsive, that is they did not respond with the same frequency to their children's verbalizations or gross motor movements. Similarly, they tended to talk less, in particular about things other than the current feeding situation.

Table 11: Ratings of cognitive growth fostering during meal times as measured by the NCAFS (Barnard 1978). Proportions scoring 'yes' answers for each item are shown for both groups.

Maternal behaviour	**No OMD (n=30)***	**OMD (n=17)***	**p level****
Provides child with objects, finger foods, toys and/or utensils	66	70	ns
Encourages and/or allows child to explore food/utensils or parent during feeding	73	76	ns
Talks to child using 2 words at least three times during session	86	82	ns
Verbally describes some aspect of food or feeding situation	41.3	12.5	0.04
Talks to child of things other than food	34	12.5	0.02
Uses statements that describe, ask questions or explains consequences of behaviour more than commands	50	50	ns
Verbalises to child within 5 seconds of child vocalisation	43	25	ns (0.06)
Parent verbalise to child within 5 seconds after child's movement of arms, legs, hands, head, trunk.	33	6	0.03
Parent does not talk baby talk	89	88	ns
Other mealtime variables	*Mean (SD)*	*Mean (SD)*	p level***
Total score (NCATS cognitive growth fostering)	4.9 (2.1)	4.2 (2.0)	ns
Mealtime duration (seconds)	1366.5	1145.0	ns

* numbers vary for each item as there was a small amount of missing data

* * chi-square

** *t-test for independent samples

2.4 Summary

Skuse et al (1992) showed that children with FTT were developmentally delayed when compared to a matched comparison group of normally developing children.

A subgroup of children with FTT were identified as having clinically significant OMD. These children tended to have abnormal scores on more than one OMC category suggesting that this was not a random finding. No evidence was found to support the argument that this subgroup was developmentally delayed when compared to children who failed to thrive yet had normal OM function.

There were a number of factors which suggest that the children with OMD may be subtly different from children with normal OM function. Although the results were non-significant they, they tended to have lower birthweights, reduced birth length, smaller head circumferences and higher perinatal and antenatal risk scores which could suggest a 'biologic vulnerability', a theory proposed by Altemeier and colleagues (1985) and discussed by Willensky et al (1995) in a recent paper. Furthermore, the children with OMD had significantly higher scores on the Waldrop scale of congenital anomalies. Ramsey et al (1993) suggested that almost half of the children they assessed with non-organic FTT had a history of questionable neurological involvement in the absence of any diagnosable neurological condition. Willensky and colleagues (1995) found that significantly more of the children who failed to thrive had a history of hypotonia reported in the first year of life as compared to the comparison children. It is difficult to draw clear conclusions from studies involving retrospective data, however, there does seem to be increasing evidence from our own study and the findings of other researchers to suggest that children with OMD display feeding related symptoms that are neurological in origin.

Both Willensky et al (1995) and Ramsey et al (1993) suggest that a history of

early feeding difficulties and persistent feeding difficulties (as evidenced by the children's refusal to accept solid foodstuffs and spitting out foods) were more prevalent in the children with FTT. In the current study of failure to thrive neither the children's early or current level of feeding difficulty, as reported by their mothers, correlated significantly with the SOMA abnormality scores. There are however, possible reasons why these differences might occur. The current study and that conducted by Willensky et al (1995) were whole population studies, whilst Ramsey and colleagues studied a clinic population. Ramsey et al (1993) had detailed medical histories for all the children seen with developmental data documented from the time the FTT was detected. Willensky et al (1995) studied a population of children in Jerusalem and Beit Shemesh where 99% attended well-baby clinics and development was regularly documented. In contrast, many of the children seen by Skuse et al (1992) did not attend clinic regularly and the data available regarding early development varied considerably. Conceivably, the children seen by Skuse et al (1994) may not have been subject to the same rigorous developmental investigations or recording of early development as the children seen in the other studies. In fact, less than 20% of the children who failed to thrive had come to the attention of paediatric departments and had investigations relating to their FTT (Skuse et al 1992).

Few psychosocial variables differentiated the 2 groups. There were no major differences in either demographic characteristics or maternal psychiatric status apart from one subscale (mothers of children with normal OM function had significantly higher scores on the subscale somatic symptoms) of the GHQ. Only

one subscale of the HOME scale discriminated the 2 groups; the findings suggest that children with OMD had fewer opportunities for exploring and playing than those children with normal OM functioning and may have been exposed to more restrictive behaviour and punishment. This finding goes against the hypothesis, proposed which suggested that children with normal OM function would have less stimulating and responsive environments which might result in a neglectful environment and be a cause of their FTT.

Finally, there were major differences in cognitive growth fostering during mealtimes, suggesting that mothers of children with OMD were less likely to talk to their children during mealtimes and did not respond to their child's physical cues. It was expected that one of the contributing factors to FTT in children with normal OM function would be a less interactive environment. However, this finding goes against the proposed hypothesis. It is interesting to speculate as to the reason for this unexpected finding. The presence of OM dysfunction could conceivably alter mother-child interaction patterns during mealtimes. Feeding is the first 'joint task' of the mother-infant relationship and any interruption of this delicate relationship, such as the extra burden of a 'difficult feeder', may place extra demands and stresses on both the child and mother and so affect the interactional style.

It has been proposed that different mechanisms cause failure to thrive and therefore different aetiologies underlie the condition. In this thesis I have proposed that the OM skills of a subgroup of children with FTT resemble the more severe deficits seen in children with CP and that a subtle neurological

disorder may exist causing the OMD. Some clinicians and researchers (for example, Ramsey et al 1993) have suggested that OMD might occur as an isolated neurological sign that only becomes apparent in some children when a more organised pattern is required by the introduction of solid foods. Such difficulties could affect the child's ability to achieve an adequate intake of food and therefore might result in FTT. There is no doubt that other aetiological factors are also of interest; whilst for a subgroup 'biologic vulnerability' might be a causative factor in others it has been proposed that environmental factors play an important role. No evidence was found to suggest that the children classified as having normal OM function were raised in a more neglectful environment with less stimulation.

2.3 Predictive validity

To date little is known about the relationship between either early FTT and later development or early OMD and later development. In children with CP it is now accepted that many of the severe growth problems can be attributed to the severity of their feeding difficulties (that is, oral, pharyngeal and oesophageal dysphagia).

There are a number of studies currently in progress which provide much needed data on the subject. They include:

- The original 1986 cohort of children who failed to thrive (now aged 8 years) are currently being followed up. Included in the study is a detailed assessment of the children's oral motor abilities, feeding behaviours and speech and language development. It is hypothesised that those children identified at 15 months of age to have OMD will be more likely to have

motor speech difficulties and that a significant proportion will continue to experience eating difficulties. An incomplete survey of the children's whereabouts between the ages of 4 and 5 years suggested that approximately 25% of the children with FTT had been referred for speech and language therapy. It was not known what proportion of these children belonged to the groups with identified OMD.

- Heptinstall et al (1987) studied a cohort of children with severe growth failure. Almost half the children, originally seen at 4 years of age, were found to have oral incoordination (for example, poor lip and jaw control, inability to chew). When seen for follow up at 10 years, 50% of the FTT group had been referred for speech and language therapy. (Skuse et al in preparation).

- The SOMA was used in a pilot study of 10 girls (6-29 months) with Turner syndrome (Mathisen et al (1992). The results showed that the girls had considerable and persistent feeding difficulties characterised by hypotonia, inability to chew, excessive loss of food and liquid, when compared to a comparison group of normally developing subjects. In addition, high arched palates were present in the majority as was frequent nasal regurgitation, gagging and vomiting. The children were recently the subject of a follow-up study aged between 4.9 and 8.4 years (x 6.4 years) (While 1995) . Fifty per cent of the girls continued to show OMD in one or more of the OMC categories administered. About half had persistent eating difficulties characterised by fussy eating behaviour,

texture intolerance, below average appetites and tendency to overload the mouth. While (1995) concluded that OMD in infancy continued to cause problems for about half of the girls in later childhood. Furthermore, just over half of the girls who were identified as having OMD in infancy either have had or were in need of speech and language therapy.

There are a number of studies currently in progress which will provide us with much needed data on the predictive validity of the SOMA. Preliminary results from the study of Turner syndrome and FTT suggest that infants identified as having significant OMD give cause for concern for later feeding, speech and aspects of language development.

B. Future development of the SOMA

There are a number of developments in progress and some planned. They include:

Current developments:

- In collaboration with colleagues from The Jerusalem Child and Family Centre, we are studying the development of oral motor function in children reared on a kibbutz. Studying such a group has distinct advantages in that many of the variables that would be difficult to control in the UK, such as the time solids are introduced and experiential factors, are more routinely standardised. In addition, factors of great interest such as motor and cognitive development are routinely assessed as is growth. The children are being studied from the time solids are first introduced and at regular intervals during the first 2 years of life. This data will enable us to

available and will provide valuable data to assist us in developing additional versions of the SOMA appropriate for younger and older age ranges.

- We are currently developing a version of the SOMA that is applicable for older children aged from 4 to 7 years of age. Some of the data will be collected in the FTT follow up study which is in progress.
- The SOMA is being applied to a variety of clinical groups including children with congenital growth syndromes, cranio-facial disorders and children with the Worster Drought syndrome (WDS). Both the WDS project and the congenital growth studies are in progress and involve studying clinical populations referred to the Paediatric Dysphagia Clinic at the Wolfson Centre. In collaboration with Ms Caroline Shipster (Speech and Language therapist at Great Ormond Street Hospital) a study of oral and pharyngeal functioning in children with Aperts and Crouzon syndrome is currently being piloted.
- The SOMA will also be used in a study examining the benefits of presurgical orthopaedics (dental plates are fitted) in cleft lip and palate babies in collaboration with the Cleft Lip and Palate Team at Great Ormond Street. Feeding, speech and language development will be followed from birth until 5 years of age. It is hoped that the project will form the basis of a Ph.D for the speech and language therapist who will be employed on the project.

Future developments:

- Comparing OM skill development in children who develop normally versus those who are developmentally delayed (in the absence of any motor deficit) would be worthwhile. Such a study would enable us to ascertain what effect contributing factors, (for example, cognition and motor development) have on OM skill development. Clinical evidence suggests that a proportion of children who are 'developmentally delayed' have normal oral motor skill development although feeding milestones (for example, self feeding) might be delayed. In contrast, others have severely delayed oral motor skills which are in line with their overall development. The difficulties in matching children for comparison purposes in such studies would need to be carefully considered.
- Future plans also include the application of the SOMA to a variety of clinical groups which will enable us to decide if there is a need for different versions, for feeding problems arising from differing aetiologies. For example, it has been suggested that it might be necessary to have a scale that is applicable for children with neurological disorders and another for children with structural problems. Only by applying the instrument to a wider range of disorders can the discriminant validity of the instrument be fully explored.
- Finally, the use of the SOMA in detecting change over time will be of great interest. Traditionally, speech and language therapists have not been able to prove the efficacy of oral motor therapy. One possible reason for this was the lack of instruments available for accurately measuring OM skills. Therefore a further application of the SOMA could be to see if

improvement in OM skills can be detected with therapy. Of greater interest in the neurologically impaired population is the use of the SOMA in decision making. Currently, speech and language therapists have no reliable and valid measure for assessing the nature and extent of OMD apart from global judgements. It is proposed that by using the SOMA it will be possible to ascertain the severity of the OMD by accurately describing for example how many OMC categories are affected. Such assessments would enable us to decide which children might require more aggressive intervention such as surgery (gastrostomy feeding). In other words children with abnormal SOMA scores for all OMC categories would be more likely to require non-oral feeding methods whereas those with textural specific OMD (for example, for cracker or solids) might be able to continue to feed adequately via oral means if their intake was restricted to the OMC categories they found easiest. The SOMA is being used in clinical practise to do just this, but to date has not been scientifically evaluated.

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Appendices:

Appendix 1.

(1.1) Reilly S, Skuse D, Mathisen B, Wolke D: The objective rating of oral motor function during feeding: development of the schedule for oral motor assessment (SOMA). Dysphagia 10, 3 (1995)

(1.2) Skuse D, Stevenson J, Reilly S, Mathisen B: Schedule for oral motor assessment (SOMA): methods of validation. Dysphagia 10, 3 (1995)

(1.3) Reilly S and Skuse D. Characteristics and management of feeding problems in young children with cerebral palsy. Dev Med Child Neurol 34: 379-388, 1992

Appendix 2.

Photographs of the equipment used in the SOMA.

Appendix 3.

Reilly S. The SOMA administration manual. (Unpublished manual available from the author)

Appendix 4.

Reilly S. The SOMA scoring manual. (Unpublished manual available from the author).

Appendix 1

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Dysphagia

The Objective Rating of Oral-Motor Functions During Feeding

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Abstract. The Schedule for Oral Motor Assessment (SOMA) was developed to record oral-motor skills objectively in infants between ages 8 and 24 months postnatal. Its aim is to identify areas of dysfunction that could contribute to feeding difficulties. The procedure takes approximately 20 min to administer, and is intended to be rated largely from a videorecording of a structured feeding session. A series of foodstuffs of varying textures, including liquids, is presented to the child in a standardized manner. Oral-motor skills are evaluated in terms of discrete oral-motor movements. The schedule distinguishes these from skills at more aggravated levels of functioning such as jaw, lip, and tongue control. A total of 127 children have been studied with the instrument, including normal healthy infants and samples with nonorganic failure to thrive, and cerebral palsy. Interrater and test-retest reliabilities were determined on a subset of 10 infants who each took part in three trials rated by 2 therapists. Excellent levels of interrater reliability (kappa > 0.75) were obtained for the presence/absence of 69% of discrete oral-motor behaviors. Test-retest reliability was similarly excellent for 85% of ratable behaviors. For the first time an assessment of oral-motor functioning has been shown to have adequate reliability for children aged 8–24 months. The validation of the SOMA on a large sample of normally developing infants and its application to clinical groups is presented in an accompanying paper [1].

Key words: Dysphagia — Oral-motor skills — Feeding — Infancy — Assessment — Deglutition — Deglutition disorders.

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The human feeding cycle is dependent on an integrated sequence of events requiring the coordination of over 20 different muscles for the movement of saliva or ingested foods from the mouth to the stomach [2,3]. Four distinct stages have been identified: the preparatory or anticipatory phase [4] which involves food getting and anticipatory reactions; the oral stage [4,5] involving bolus management and transfer, sucking, munching, and mastication; the pharyngeal phase [5] during which swallowing occurs; and finally the esophageal phase which begins with relaxation and opening of the upper esophageal sphincter [6]. There may be dysfunction of this highly complex process at any one or more levels resulting in feeding difficulties. Such problems may be congenital or acquired and anatomical or functional in nature [7].

There is increasing recognition of the range and prevalence of feeding disorders in infancy and the significance of such difficulties for both the child and caretakers [8–13]. Approximately 39% of developmentally disabled children have been described as having severe feeding problems [14,15] and there is increasing evidence to suggest that some developmentally disabled infants are unable to achieve an adequate nutritional intake because of the severity of their oral-motor dysfunction [16]. Despite this there is a paucity of information about the development and evaluation of oral-motor functioning in young children. Therapists have attempted to devise effective treatments for the eating-impaired child, but until recently, there were few objective methods of rating oral-motor skils and little if any data on important aspects of the functioning of normal children [17–20]. As yet, there is no satisfactory comprehensive oral-motor assessment for evaluating function in infants who are receiving mixed feeds.

Methods are available for assessing dysphagia in adults with acquired neurological disorders or structural problems [5,21–23]. They are usually dependent on the

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patient's ability to follow verbal instructions, and require clear cooperation with the examiner. Administration of such assessments to children would at best provide limited information and, perhaps worse, lead to misleading or incorrect conclusions about the functional integrity of oral-motor skills. Adult assessments were developed for the mature oral-motor system; abnormal performance which represents a deficit in an adult could simply reflect age-appropriate performance in an infant or young child.

The development of sucking and swallowing skills in young infants has been well documented [24–28]. A number of studies have suggested that neonatal feeding behavior is a sensitive indicator of central nervous system integrity in neonates [29–33]. In order to provide an objective method of rating the acquisition of these skills, Leaf and Gisel [34] developed an observation method for analyzing sucking, and Braun and Palmer [35] developed the Neonatal Oral Motor Assessment Scale (NOMAS). Both are applicable only to the neonatal population, as are certain other innovative techniques [29,36–38]. Until recently there have been very little data available on the acquisition of oral-motor skills in later infancy and early childhood [17,18,20].

Although methods for assessing oral-motor functioning in infants and young children do exist [7,38,40–44], they all have significant limitations. The literature is essentially descriptive, discussing the development of oral-motor skills and highlighting areas that should be included in an evaluation; "feeding checklists" have been developed primarily for use with disabled children, such as those with cerebral palsy (CP) [45,46]. The Prespeech Assessment Scale (PSAS) devised by Morris [42] is the most comprehensive scale developed to date. It evaluates control of oral secretions, eating, pre-speech vocal behaviors, and early speech development in developmentally disabled infants and children. However, the scale suffers from the serious limitation that judgments about what are "normal" and "abnormal" behaviors at specific developmental ages are based upon norms that have been derived from an inadequate sample. Morris studied the development of feeding patterns in just 6 normal children at intervals of 3 months for a period of from 12 to 24 months. Furthermore, the scale's reliability data, calculated on the basis of percentage of agreement among therapists, ignore the extent of agreement by chance and is therefore inadequate [47].

Kenny et al. [7] developed a Multidisciplinary Profile for use with severely disabled children which they demonstrated to possess good reliability. The profile is divided into six sections: physical/neurological, oral-facial structure, oral-facial sensory inputs, oral-facial motor function, ventilation/phonation, and functional feeding assessment. It is designed to be administered by a range of different health professionals, in a variety of settings, and takes approximately 45 min to administer. The profile was designed for developmentally disabled children and pilot tested on 8 such subjects who were dependent feeders. Kenny et al. [7] considered dependent feeders to be the most functionally disabled individuals and those most likely to be considered for nonoral feeding methods. Stratton's [43] "Evaluation of Oral Function in Feeding" measures a limited number of skills [9], was not standardized on normal children, and has been shown to have only marginally acceptable reliability [48].

Sheppard [44] developed a model for the Preschool Oral Motor Examination to be used by clinicians working with children with CP and various other populations of at-risk infants. There are eight sections to the examination which include the history, peripheral speech-mechanism examination, oral reflexes, oral postural control, control of oral secretions, eating, voluntary, and nonverbal and vocal behaviors. No details are given regarding normative data or reliability.

Gisel and Patrick [16] compiled a scale of 14 abnormal oral-motor behaviors and compared the performance of children with CP with weight-matched, healthy controls, many of whom were substantially younger in age. Two textures of food—puree and solids—were used to assess the children. No normative data or measures of interrater reliability were provided. Vulpe's [39] Developmental Feeding Assessment Scale rates children's abilities in different domains of eating behaviors but does not lend itself to the quantification of specific oral-motor behaviors.

In summary, the majority of pediatric oral-motor assessments currently available have a number of limitations; first, they were developed primarily for use with a severely neurologically impaired population and therefore cannot satisfactorily be applied to children with relatively minor degrees of dysfunction. Recent research has shown that oral-motor disorders in infancy are not limited to those with overt neurological conditions [9,49,50]. Secondly, oral-motor behaviors are not assessed in a standardized manner using a variety of food textures; texture has been shown to be an important factor affecting the oral-motor performance of infants and young children [19]. Thirdly, norms have not been established for the developmentally appropriate oral-motor skills of neurologically intact subjects during infancy and early childhood. Accordingly, there is an urgent need for the development of a valid and reliable measure of oral-motor functioning, applicable to a relatively wide age range of young children, which incorporates the rating of exposure to a range of food textures [7,47,48].

The aim of this paper is to describe the development of such a schedule—the Schedule for Oral Motor Assessment (SOMA)—which has been designed to as-

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sess a wide range of oral-motor skills in infancy. The scale was originally designed to detect oral-motor dysfunction in children with a grossly intact neurological system but it has been extended for use in children with both minor and major neurological impairment. It should be applied in conjunction with a range of other developmental assessments and procedures. We describe the rationale behind the design of the schedule and the procedures that were undertaken to establish test-retest and interrater reliability. An accompanying paper describes the validation of the SOMA [1].

Patients and Methods

Three groups of infants were studied; a comparison group of 58 normal infants, 56 infants with nonorganic failure to thrive (NOFT), and 13 infants with a confirmed diagnosis of cerebral palsy (CP) [10]. They ranged in age from 8 to 44 months. The mean age of the comparison group was 12.2 months (range 8–21.2 months), the NOFT children 15 months (range 8.75–19.5 months), and the children with CP, 20.2 months (range 14.2–44 months).

The children in the NOFT group were selected largely from an inner-city whole population survey of 1,558 full-term singletons, born between January 1st and December 31st, 1986, who were registered with participating child health clinics or family doctor practices. Confirmed cases of growth faltering had to have a birthweight within the normal range at term and to have fallen by 9 months of age to a weight for age below the third population percentile of the National Center for Health Statistics Growth Standards [51]. Serious organic disease, as a cause for the failure to thrive, was excluded on the basis of a range of standardized pediatric investigations. The comparison group (n = 47), which was chosen from the population database, was matched to the 47 confirmed cases on the basis of, sex, age, ethnic origin, birthweight (to within 300 g), ordinal position, and socioeconomic status. A further 9 NOFT and 11 comparison subjects were recruited during a pilot study for the same investigation [8,9].

Procedures

Each family was visited at home and data were usually collected during one home visit, although occasionally two visits were necessary. The visit comprised three parts: (1) a semistructured feeding interview with the child's primary caretaker, in most cases the child's mother; (2) a video recording of the child's main meal of the day; and (3) the SOMA, which will be discussed in detail, was administered. Other procedures have been described in earlier publications [8–10,49].

Schedule for Oral Motor Assessment

The SOMA was administered to each child approximately 1–2 h after the child's main meal, in most cases, lunch. The examination took on average 20 min. The examiner aimed to achieve the best seating position possible within the family's resources but some families did not possess high chairs or those available were inadequate. For example, in certain cases, less than ideal support was provided for hypotonic infants. All SOMA procedures were video recorded using a JVC color camera (Newvicon) which was either hand held, supported on a table, or mounted on a tripod. Natural lighting was used. The camera was sensitive to low light conditions (15 lux), had a built-in stop watch, a powerful zoom facility, automatic exposure control, and automatic focusing. The assessment procedure was filmed by the mothers following a brief demonstration and practice session; they were positioned so that the view of the child's head and neck was taken from an oblique angle. The examiner was positioned in front of the child so that all food was presented in the midline.

Instrument Design and Development

The SOMA was developed to fulfill two purposes: to enable us to objectively record the oral-motor skills of infants between the ages of 8 and 24 months and to use the assessment to evaluate oral-motor function in children with either no overt neurological dysfunction or those with minor degrees of dysfunction. Because preexisting oral-motor assessments had been developed primarily for use with individuals who had severe oral-motor dysfunction resulting from neurological impairment, they were not applicable to the infants we wished to study.

During the developmental phase it became clear that the SOMA should meet a number of basic requirements. First, it was essential that the child's oral-motor skills should be challenged with a variety of textures. Although developmental trends in the normal process of oral-motor skill acquisition following the introduction of mixed feeding have been noted by various researchers, the process has not been adequately described [19,52]. Variation has been noted in both the age at which the infants' first solids are introduced and when foods of increasing texture are offered to them [9]. Some infants will therefore have had a wide range of oral-motor experiences with exposure to a variety of different tastes and textures whereas others may have had rather limited experience.

Second, the manner in which the food and liquid is presented should be standardized. Recent evidence has confirmed that oral-motor performance varies according to the texture or implement used during feeding [19]. Our own experience during pilot work showed that the way in which some mothers fed their children could affect their oral-motor performance. For example, some mothers tended to tilt the spoon upwards when they withdrew it from their child's mouth, thus enabling the child to remove the food more easily. In addition, they often used the spoon to clean their children's lips of any remnants of food, the result being that we were unable to observe either the child's ability to remove food from the spoon unaided or the combined action of the lips and teeth to clean the lips.

Finally, the need for a standard set of feeding utensils was established. As a result of pilot work it became clear that the use of ordinary opaque plastic utensils was not ideal. It was often difficult to observe some oral-motor behaviors and to ascertain if indeed the food had been removed from the spoon or liquid taken from the cup. Accordingly, in conjunction with a leading manufacturer of infant feeding equipment (Cannon Babysafe), a standard set of feeding utensils was developed (spoons, bottles, cups, and teats). The utensils were constructed of clear, nonbreakable plastic so that lip and tongue movements were clearly visible, as was the amount of liquid in the bottle or cup. The design of the equipment resembled that commonly used by children in the 12–18 month age range.

An administration manual (SOMA) was developed to meet the above requirements, in particular to assist in standardizing the type of foodstuffs used and to detail exactly how the foodstuffs and liquids were presented to the infants. Criteria were established for the manner of spoon presentation and the amount of food/liquid presented. A sample page from the SOMA Administration Manual and one from the Scoring Manual are included in the appendix.

Six oral motor challenge (OMC) categories ranging from liquid (OMC-1), puree (OMC-2), semisolid (OMC-3), solid (OMC-4), biscuits (OMC-5), and dried fruit (OMC-6) were included in the SOMA (Fig. 1). They were chosen on the basis that infants in that age range should be capable of coping with each of them satisfactorily, but a

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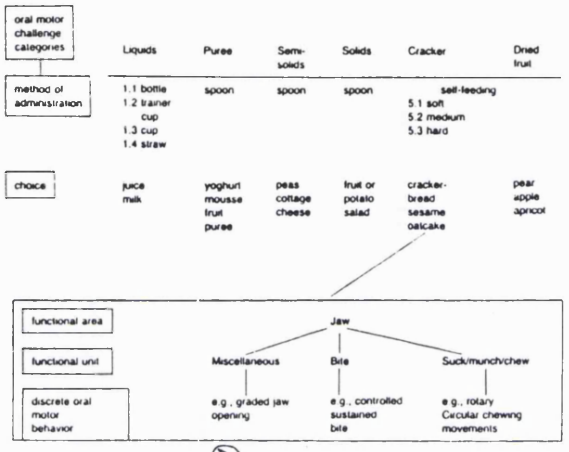

Fig. 1. The four components of the FAS are shown: oral motor challenge categories, functional units and discrete oral motor behaviors.

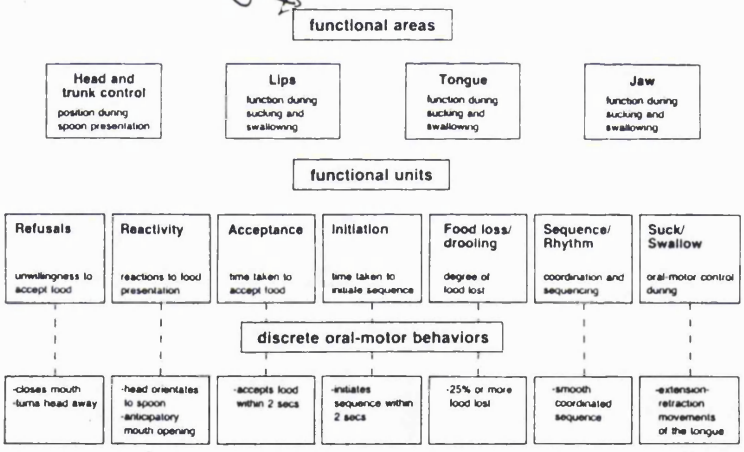

Fig. 2. Functional areas, functional units, and examples of some of the discrete oral-motor behaviors relevant to OMC-2 (puree).

varying degree of oral-motor expertise would be required for each category. Decisions as to which OMC categories to include were based on preexisting knowledge of the introduction of foods and liquids to the majority of children in Western society (46,53–55). In addition, the experienced pediatric speech pathologists (SR and BM) piloted the procedures in order to confirm which foods were socially and culturally acceptable to a wide range of infants.

We decided to administer three trials of each OMC category because there was no clear evidence to indicate whether the oral-motor performance of infants and young children is consistent from one feeding session to the next. In addition, the effect of feeding challenging textures, that is, ones outside the child's usual range of experience, has not been established. These three trials were administered by the examiner and followed by a fourth trial during which the infant was given the opportunity to self-feed. There were a number of advantages to the examiner (SR or BM) administering the main trials to the child. It ensured a standard presentation without undue assistance, and in addition permitted the making of a number of on-the-spot ratings of oral-

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Table 1. Functional areas—puree and semisolids

Functional areas	Puree				Semisolids			
	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability
Lip								
lip1 lower lip draws inwards around spoon	0	1	0.77	0.87	0	1	0.35	1
lip2 upper lip removes food from the spoon	0	1	0.7	0.5	0	1	0.35	1
lip3 lower/upper lip used to clean	0	1	0.52	0.74	0	1.07	0.47	1
lip4 lower lip behind upper teeth sucking	1	1	0.59	1	1	1	0.45	1
lip5 lip retraction	1*	1	1	1	1*	1	1	1
lip6 purse string retraction	1*	1	1	1	1*	1	1	1
lip7 lips close around stimulus	0	1	1	1	0	1	1	1
lip8 lips close during suck/munch/chew	0	1	0.46	1	0	1	0.62	1
lip9 lips closed intermittently during suck/munch	0	1	0.6	1	0	1	1	1
lip10 upper lip active suck/munch/chew	0	1	0.61	0.85	0	1	0.83	1
lip11 lower lip active during suck/munch/chew	0	1	0.39	1	0	1	0.64	1
lip12 lip angles/cheeks active	0	0.78	0.39	0.88	0	1	0.5	1
lip13 lip angles/cheeks swallow	0*	0.92	0.42	1	0	0.8	0.8	1
Tongue								
ton1 elevation/depression	0*	0.44	0.4	1	0*	0.93	1	1
ton2 extension/retraction	0*	0.44	1	1	0*	0.93	1	1
ton3 tongue tip elevation	0*	0.15	**	1	0*	1	0.3	1
ton4 cupping/thinning	0*	0.65	**	1	0*	0.65	0.63	1
ton5 thick-bunched tongue	1*	0.78	0.78	1	1*	0.93	1	1
ton6 gross tilting/rolling	.	.	.	1	0*	0.93	0.42	1
ton7 center-side lateralization	.	.	.	1	0*	0.93	0.07	1
ton8 side-center lateralization	.	.	.	1	0*	0.93	0.02	1
ton9 side-side lateralization	.	.	.	1	0*	0.93	0.1	1
ton10 transient minimal protrusion	0	0.79	0.35	0.73	0	0.93	0.62	1
ton11 consistent considerable protrusion	1	0.78	0.47	0.87	1	1.06	0.56	1
ton12 protrusion beyond incisors	0	0.78	0.48	1	0	1	0.75	1
ton13 protrusion beyond lips	1	0.78	0.37	0.84	1	1	1	1
ton14 tongue thrust	1	0.78	1	1	1	1	1	1
ton15 asymmetry	1	0.78	1	1	1	1	1	1

Behavioral status: 0 = passed, 1 = failed.
*DOM behaviors not included in the final analysis.
**Indicates that there were too few ratable DOM behaviors to compute a kappa.
.Indicates not applicable to that OMC.

motor behaviors, such as tongue function, which could not have been seen on the videotape.

Occasionally, children refused to be fed by the examiner and in such situations the mother was given instructions and a demonstration of how to present the food. There was a suitable pause between each mouthful and the child's mouth was checked by the examiner to ensure that the child had swallowed and that no remnants of food remained in the oral cavity. At least two choices of food were available for each OMC category (Table 1 gives details of choices offered). Mothers were asked to indicate which choice of food she thought her infant would prefer. If the infant refused or showed dislike for the first food, the alternative was offered.

The oral-motor control required for drinking was assessed in four test situations: during breast or bottle feeding (OMC-1.1), drinking from a trainer cup (a cup with a spouted lid) (OMC-1.2), drinking from an ordinary cup (OMC-1.3), and straw drinking (OMC-1.4) as detailed in Table 1. Where a mother was breast-feeding, the procedure was filmed by the examiner. The oral-motor control required for solid foodstuffs such as puree (OMC-2), semisolids (OMC-3), and solids (OMC-4) were assessed during spoon-feeding whereas OMC-5 (biscuits) and OMC-6 (dried fruit) were finger-fed by the examiner. In an attempt to standardize the quantity of biscuit bitten off by a child, the examiner's thumb and forefinger were positioned approximately 3/4 inch from the end being presented to the child. It was not uncommon for

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Table 2. Functional area—puree and semisolids

Functional areas	Puree				Semisolids			
	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability
Jaw								
jaw1 graded jaw opening	0	1	0.42	0.73	0	1	0.4	1
jaw2 internal stabilisation	0	1	1	1	0	1	1	1
jaw3 external stabilisation required 100%	1	1	1	1	1	1	1	1
jaw4 external stabilisation required 50%	1	1	1	1	1	1	1	1
jaw5 vertical movements	0	1	1	1	1	1	1	1
jaw6 lateral jaw movements	.	.	.	1	0	1	0.4	1
jaw7 circular/rotary movements	.	.	.	1	0	1	0.58	1
jaw8 wide vertical excursions	1	1	1	1	1	1	0.35	1
jaw9 small vertical excursions	0	1	1	1	0	1	0.62	1
jaw10 associated jaw movements	1	1	0.49	1	1	1	1	1
jaw11 associated head movements	1	1	1	1	1	1	0.44	1
jaw12 uses fingers to transfer food	1	1	0.77	1	1	1	0.42	1
jaw13 clenching/thrusting	1*	1	1	1	1	1	1	1
Functional units								
Reactivity								
react1 head orientation to spoon/teat, etc	0	1	0.54	0.75	0	1	0.64	1
react2 anticipatory mouth opening	0	1	1	1	0	1	1	1
react3 increase in tension	1	1	0.88	0.86	1	1	1	1
react4 immediate removal food/liquid	1	1	1	1	1	1	1	1
react5 no food/liquid enters mouth	1	1	1	1	1	1	1	1
Acceptance								
accept1 accepted within 2 seconds	0	1	1	0.73	0*	1	0.77	1
accept2 time taken to accept food (>2 sec)	1*	0.23	**	1	1	0.35	**	1

Behavioral status: 0 = passed, 1 = failed.
*DOM behaviors not included in the final analysis.
**Indicates that there were too few ratable DOM behaviors to compute a kappa.
.Indicates not applicable to that OMC.

children to refuse to accept the biscuits and dried fruit either from the examiner or their mothers; in such cases, the food was given to the child to self-feed.

Design

The SOMA was designed to be rated from video recordings, apart from a small number of on-the-spot ratings, such as tongue movements, which could not always be easily seen from the video. Whenever possible the examiner used verbal description to assist with later video analysis or recorded the behaviors on a score sheet. The tapes were rated from playback on professional quality machines (JVC BR6400TR), with a slow play and frame-by-frame facility.

Each of the six OMC categories can be described on three levels: functional areas (FA), functional units (FU), and discrete oral-motor behaviors (DOMs) as illustrated in Table 1. FA refers to the muscle group or structure being investigated, for example, lip function. FU describes the activity that the muscle group(s) or structure(s) participate in or perform, for example, the role of the lips in preventing food loss. DOM behavior refers to the individual oral-motor movements that prevent food loss, for example, the upper lip moves downwards to assist in removing food from the spoon and in doing so helps to prevent any food loss. In Figure 2, an example is given of the FAs, FUs, and DOMs that are relevant to just one OMC category, OMC-2 (puree). A definition of each FA and FU is given and examples are provided of DOM behaviors that correspond to the functional unit.

An exhaustive list of DOM behaviors was compiled for each OMC category by SR and BM on the basis of their clinical experience and a thorough review of the literature on both the development of normal and abnormal oral-motor skills during infancy. Not all DOM behaviors were applicable to all OMC categories, for example, lateral tongue movements would be applicable to the oral management of solid textures such as OMC-5 and OMC-6 but not to OMC-1 or OMC-2 (liquid and puree).

Between 75 and 90 DOM behaviors were compiled for each OMC category; the more challenging the foodstuff (e.g., OMC-6), the more DOM behaviors that were included. The DOM behaviors were grouped into 10 FUs including refusals, reactivity, acceptance, initia-

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Table 3. Functional units—puree and semisolids

Functional units	Puree				Semisolids			
	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability
Initiation								
init1 sequence initiated within 2 sec	0	1	0.69	0.71	0	0.87	1	1
init2 time taken to initiate sequence (>2 sec)	1*	0.34	**	1	1*	0.36	**	1
init3 numerous attempts to sequence	1	1	0.47	0.71	1	0.93	0.58	1
init4 no. of attempts to initiate sequence-motor movements	1*	**	**	**	1	**	**	**
Food loss/Drooling								
food loss1 less than 25% lost	0	1	0.71	0.47	0	1	0.78	0.75
drool1 consistent/considerable drooling	1	1	1	1	1	1	0.47	1
drool2 asymmetrical	1	1	1	1	1	1	1	1
Sequencing								
seq1 smooth rhythmic sequence	0	1	0.83	0.84	0	0.93	0.47	0.7
seq2 panic reactions	1	1	0.64	0.85	1	0.93	0.63	1
seq3 choking	1	1	1	1	1	0.93	1	1
Swallowing								
swal1 jaw alignment	0*	0.55	1	1	0*	0.85	1	1
swal2 lip closure	0*	0.55	0.36	1	0*	0.85	0.29	1
swal3 increase in tension	1*	0.55	1	1	1*	0.62	1	1
swal4 panic reactions	1*	0.55	1	1	1*	0.85	1	1
swal5 no swallow observed	1*	0.72	0.45	0.81	1*	1	1	1
swal6 uses gravity head extension	1*	0.6	1	1	1*	0.85	1	1
swal7 numerous attempts to initiate	1*	0.61	1	1	1*	0.86	0.28	1
swal8 nasal regurgitation	1	1	1	1	1*	0.86	1	1
swal9 gagging	1	1	0.49	1	1*	0.86	1	1
swal10 vomiting	1	1	1	1	1*	0.86	1	1
swal11 choking	1	1	1	1	1*	0.79	1	1

Behavioral status: 0 = passed, 1 = failed.
*DOM behaviors not included in the final analysis.
**Indicates that there were too few ratable DOM behaviors to compute a kappa.

tion, food/liquid loss, drooling, sequencing/rhythmicity, sucking/munching/chewing, swallowing, and biting. The number of FUs varied between OMC categories depending on the type and degree of oral-motor expertise required. For example, the functional unit biting is relevant to OMC-5 and OMC-6 (biscuits and dried fruit), but not to OMC-2 (puree).

Scoring

Two scoring categories were devised to include ratable and nonratable responses. Nonratable responses included child refusals, items that were omitted, and items that proved exceptionally difficult to rate. Omitted items occurred only occasionally, in most cases because of technical difficulties or if there had been an administration error. Some DOM behaviors were nonratable because they were not easily observed, such as lateral tongue movements.

Ratable responses were scored dichotomously, according to whether the behavior was present or absent. Each DOM behavior was rated individually. All three trials of each of the 6 OMC categories were rated, resulting in a minimum of at least 75 DOM behaviors that were rated for each trial and not less than 225 behaviors rated for each OMC category.

For the purposes of the validation exercise [1] it was necessary to make decisions regarding the status of each DOM behavior, that is, whether the presence or absence of a behavior could be considered a failed or passed response. Where possible, decisions were supported by references in the literature that defined normal and abnormal oral-motor behavior in infants aged 12–18 months. Developmental age, as in other areas of child development, was an important factor in the decision-making process. For example, the absence of a particular behavior in a child aged 6 months may not necessarily be considered a failed response, whereas absence of the same skill during the latter stages of infancy would be considered a failed response. Young infants are often unable, for example, to use their upper and lower lips to clean the spoon and do not use rotary jaw movements when munching solid textures. However, by the later stages of infancy these DOM behaviors would be part of the infants oral-motor repertoire. Similarly, texture was also an important factor: the absence of some DOM behaviors such as lateral tongue and jaw movements for OMC-2 (puree) or OMC-3 (semisolids) would not be considered failed responses whereas their absence when dealing with a more challenging texture such as OMC-5.3 would be considered a failed response. There is evidence to suggest that normal children use the method requiring the least effort for dealing with food orally [19]. They will, for example, often ingest more solid foods such

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Table 4. Functional areas—solids and cracker

Functional areas	Solids				Cracker			
	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability
Lips								
lip1 lower lip draws inwards around spoon	0	0.93	0.83	0.56	.	.	.	.
lip2 upper lip removes food from the spoon	0	0.93	0.74	0.81	.	.	.	.
lip3 lower/upper lip used to clean	0	0.93	0.6	1	0	0.86	1	1
lip4 lower lip behind upper teeth sucking	1	0.93	1	1	1	0.93	0.56	0.5
lip5 lip retraction	1*	0.93	1	1	1*	0.93	1	1
lip6 purse string retraction	1*	0.83	1	1	1*	0.93	1	1
lip7 lips close around stimulus	0*	1	1	1	0	1	0.74	1
lip8 lips close during suck/munch/chew	0	0.93	0.2	0.42	0	1	1	1
lip9 lips closed intermittently during suck/munch	0	0.93	0.41	0.12	0	1	1	1
lip10 upper lip active suck/munch/chew	0	0.93	0.64	0.8	0	1	0.3	1
lip11 lower lip active during suck/munch/chew	0	0.93	0.41	0.8	0	1	0.62	1
lip12 lip angles/cheeks active	0	0.93	0.4	1	0	1	0.32	0.5
lip13 lips closed during swallow	0*	0.92	0.4	1	0*	1	0.32	1
Tongue								
ton1 elevation/depression	0*	0.71	1	1	0*	0.63	1	1
ton2 extension/retraction	0*	0.71	1	1	0*	0.56	1	1
ton3 tongue tip elevation	0*	0.52	**	1	0*	0.89	0.45	1
ton4 cupping/thinning	0*	1	**	1	0*	1	1	1
ton5 thick-bunched tongue	1*	0.71	**	1	1*	0.24	1	1
ton6 gross tilting/rolling	0*	0.71	**	1	0*	0.29	1	1
ton7 center-side lateralization	0*	0.45	**	1	0*	0.71	1	1
ton8 side-center lateralization	0*	0.5	**	1	0*	0.71	**	1
ton9 side-side lateralization	0*	0.6	**	0.74	0*	0.81	**	1
ton10 transient minimal protrusion	0	0.6	1	0.54	0	1	0.62	1
ton11 consistent considerable protrusion	1	0.6	1	1.01	1	1	0.52	1
ton12 protrusion beyond incisors	0	0.6	1	0.79	0	1	0.62	1
ton13 protrusion beyond lips	1	0.6	1	1	1	1	0.42	1
ton14 tongue thrust	1*	0.6	1	1	1*	1	1	1
ton15 asymmetry	1*	0.6	1	1	1*	1	1	1

Behavioral status: 0 = passed, 1 = failed.
*DOM behaviors not included in the final analysis.
**Indicates that there were too few ratable DOM behaviors to compute a kappa.
.Indicates not applicable to that OMC.

as semisolids by sucking or munching instead of using a more mature chewing pattern. Finally, where no data were available from previous studies, decisions were made on the basis of the raters' (SR and BM) clinical experience in evaluating the oral-motor skills of more than 100 normally developing children. As a result, each DOM behavior was recoded so that a score of 1 represented a failed response and 0 a passed response; these are indicated in the column headed Behavioral Status in Tables 1–8.

Interrater Reliability

A random selection of 10 video tapes (7 NOFT and 3 comparisons) was made by an independent researcher (DW). Two speech pathologists, blind to subject status, rated each tape independently. We have found that the raters' ascertainment of case-comparison status was no better than chance. The speech pathologist undertaking the reliability study underwent detailed training in the administration and scoring methods of the SOMA which were organized by SR. All three trials of each food/liquid category were rated, resulting in a total of 30 ratings for each discrete behavior.

Two separate sets of interrater reliability ratings were computed: (1) the agreement between independent raters as to whether a behavior was ratable or nonratable (stage 1) and (2) agreement on pass/fail for ratable items (stage 2). Where there was poor agreement on the "ratability" of a DOM behavior (stage 1), this behavior was excluded from stage 2. For example, if there were disagreements on 5 of the 30 pairs of ratings in stage 1, then only 25 pairs of ratings were entered into stage 2.

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Table 5. Functional areas and units (solids and cracker)

	Solids				Cracker			
Functional areas	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability
Jaw								
jaw1 graded jaw opening	0	1	0.42	0.47	.	.	.	.
jaw2 internal stabilization	0	0.93	1	1	0	0.93	1	1
jaw3 external stabilization required 100%	1	0.93	1	1	1	0.93	1	1
jaw4 external stabilization required 50%	1	0.93	1	1	1	0.93	1	1
jaw5 vertical movements	0	0.75	1	0.78	0	1	1	1
jaw6 lateral jaw movements	0	0.77	0.4	0.54	0	1	0.35	1
jaw7 circular/rotary movements	0	0.77	0.52	0.54	0	1	0.4	1
jaw8 wide vertical excursions	1	0.77	1	0.78	1	1	0.62	1
jaw9 small vertical excursions	0	0.77	1	1	0	1	1	1
jaw10 associated jaw movements	1	0.85	1	1	1*	1	1	1
jaw11 associated head movements	1	0.93	1	1	1	1	1	1
jaw12 uses fingers to transfer food	1	0.93	1	0.62	1	1	1	1
jaw13 clenching/thrusting	1	0.93	1	1	1	1	1	1
Functional units								
Reactivity								
react1 head orientation to spoon/teat, etc	0	1	0.78	1	0	1	0.77	1
react2 anticipatory mouth opening	0	1	0.69	1	0	1	1	0.82
react3 increase in tension	1	1	1	0.87	1	0.86	0.46	0.69
react4 immediate removal food/liquid	1	1	0.46	0.6	1	1	0.85	0.4
react5 no food/liquid enters mouth	1	1	0.6	0.5	1	1	0.48	1
Acceptance								
accept1 accepted within 2 seconds	0	1	1	0.86	0	0.87	1	1
accept2 time taken to accept food (>2 sec)	1*	**	**	1	1	**	**	1
Initiation								
init1 sequence initiated within 2 sec	0	0.93	1	0.82	0	1	1	1
init2 time taken to initiate sequence (>2 sec)	1*	**	**	1	1*	**	**	1
init3 numerous attempts to sequence	1	1	1	1	1	1	1	1
init4 no. of attempts to initiate sequence	1*	**	**	1	1	**	**	1

Behavioral status: 0 = passed, 1 = failed.
*DOM behaviors not included in the final analysis.
**Indicates that there were too few ratable DOM behaviors to compute a kappa.
.Indicates not applicable to that OMC.

Interrater reliability was computed using the kappa statistic, a chance-corrected agreement coefficient (56,57). The Kappa ranges suggested by Landis and Koch [58] with respect to the degree of agreement were adopted. That is, values greater than 0.75 represent excellent agreement beyond chance, values between 0.40 and 0.75 represent fair to good agreement, and values below 0.40 poor agreement. Tables 3–13 show stage 1 and 2 kappa values for each DOM behavior and the five final OMC categories.

Kappa values were calculated for 168 DOM behaviors for OMC category 1 (liquid–bottle, trainer cup, and cup). For stage 1 (ratable/nonratable), median kappa values of 1 were obtained on 87% of the behaviors, 9% were greater than 0.75, 2% were between 0.40 and 0.75, and 2% were below 0.40. Sixty-eight percent of stage 2 ratings resulted in perfect agreement, 9% were greater than 0.75, 13% were between 0.40 and 0.75, and 2% were less than 0.40.

Kappa values were calculated for 268 DOM behaviors and summarized for oral-motor challenge categories 2, 3, 4, and 5 (puree, semisolids, solids, and cracker). For stage 1 interrater reliability (ratable vs. nonratable) median kappa values of 1 (indicating perfect agreement) were obtained on 58% of the behaviors, 28% of behaviors had median kappa values greater than 0.75 (excellent agreement), 13% were between 0.40 and 0.75 (fair to moderate), and only 1% were below 0.40 (poor agreement). The results of stage 2 (ratable responses) indicated that 56% of the median kappa values were 1, 6% were greater than 0.75, 28% were between 0.40 and 0.75, and 10% were below 0.40.

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Table 6. Functional units—solids and cracker

	Solids				Cracker			
Functional units	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability
Food Loss/Drooling								
food loss1 less than 25% lost	0	1	1	0.68	0	1	1	1
drool1 consistent/considerable drooling	1	1	1	0.69	1	1	1	1
drool2 asymmetrical	1*	1	1	1	1	1	1	1
Sequencing								
seq1 smooth rhythmic sequence	0	0.79	0.52	0.64	0	1	0.84	0.2
seq2 panic reactions	1	0.65	0.74	0.85	1*	1	1	1
seq3 choking	1	0.79	1	1	1*	1	1	1
Swallowing								
swal1 jaw alignment	0*	1	1	1	0*	0.56	0.33	1
swal2 lip closure	0*	1	0.21	1	0*	0.56	1	1
swal3 increase in tension	1*	1	1	1	1*	0.66	1	1
swal4 panic reactions	1*	1	1	1	1*	0.66	1	1
swal5 no swallow observed	1*	1	1	1	1*	0.92	0.33	1
swal6 uses gravity head extension	1*	1	1	1	1*	0.66	**	1
swal7 numerous attempts to initiate	1*	1	1	1	1*	0.66	1	1
swal8 nasal regurgitation	1	1	1	1	1*	0.71	1	1
swal9 gagging	1	1	1	1	1	1	1	1
swal10 vomiting	1	1	1	1	1*	1	1	1
swal11 choking	1	1	1	1	1*	1	0.26	1
Bite								
bite1 tongue passive under food	.	.	.	.	0	1	0.38	1
bite2 tongue thrust interference	.	.	.	.	1	1	0.6	1
bite3 anticipatory tongue movements	.	.	.	.	0	1	0.44	1
bite4 phasic bite	.	.	.	.	1	1	1	1
bite5 associated head extension	.	.	.	.	0	1	1	1
bite6 associated head extension	.	.	.	.	1	1	0.31	1
bite7 tonic bite	.	.	.	.	1	1	1	1
bite8 graded jaw opening	.	.	.	.	0	1	1	1
bite9 biscuit broken off with hands	.	.	.	.	1	1	0.1	0.21

Behavioral status: 0 = passed, 1 = failed.
*DOM behaviors not included in the final analysis.
**Indicates that there were too few ratable DOM behaviors to compute a kappa.
.Indicates not applicable to that OMC.

Test-Retest Reliability

Using the same 10 video tapes selected for the interrater reliability study, we compared the results of trial 1 with those of trial 3 in order to evaluate test-retest reliability using the kappa statistic; only ratable responses were included. The results of the kappas obtained for each DOM behavior are shown in Tables 1–8. Kappa values of 1 (indicating perfect agreement) were obtained on 84% of the DOM behaviors; 6.2% were greater than 0.75 (excellent agreement), 8.7% were between 0.40 and 0.75, and only 1.1% were below 0.40.

Missing Data

Preliminary analysis showed that there were occasional subsets of missing data. For example, some children initially accepted the food/liquid and then spat it out; if children sucked, munched, or chewed with lip closure, tongue movements could not be observed and rated. Some trials were therefore incomplete. Where there were missing data for trial 1, trial 3 data were substituted. If both trials 1 and 3 were missing, trials 2 and 4 would be substituted. Although this procedure considerably reduced the amount of missing data, any behavior with missing data in 30% or more children was excluded from the analysis. The discrete oral-motor behaviors not included are shown in Tables 1–8.

The refusal rate varied according to the texture offered to the children. There was little difference between the refusal rate for trial 1 and 3, therefore refusals were summed for both trials. The highest refusal rate occurred on texture 3 (solids 41.5%) and texture 6 (dried fruit 40.5%). The lowest rates of refusal were for liquid 1 (bottle 22%) and texture 5 (medium cracker 21.6%). Refusal rates for other textures ranged from 24.5% (liquid 4—straw) to 34.6% (texture 2—semisolids). The children with CP had the lowest refusal rate for all textures and the NOFT children tended to refuse less than the comparison children.

Body and head positioning, degree of head support required, refusal behaviors, and adaptive skills were not included in the final analysis. Although they were considered essential clinical components,

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Table 7. Functional areas—bottle, trainer cup, cup

Functional areas	Bottle				Trainer cup				Cup			
	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability
Lips												
lip1 marked lip retraction	1*	1	1	1	1*	0.93	1	1	1*	1	1	1
lip2 purse string reaction	1*	1	1	1	1*	0.93	1	1	1*	1	1	1
lip3 firm contact upper lip	0	1	1	1	0	0.92	0.64	1	0	1	0.38	1
lip4 firm contact lower lip	0	1	1	1	0	0.93	0.64	1	0	1	0.38	1
lip5 intermittent/incomplete upper lip	1	1	1	1	1	0.93	0.64	1	1	1	0.53	1
lip6 intermittent/incomplete lower lip	1	1	1	1	1	0.93	0.64	1	1	1	1	1
lip7 lips closed during swallow	0	1	0.63	1	1	1	0.64	1	1	1	0.57	0.8
lip8 lips open during swallow	1	1	0.63	1	1	1	0.64	1	1	1	0.57	1
Tongue												
ton1 elevation/depression	0*	0.36	**	**	0*	0.65	**	1	0*	0.63	**	1
ton2 extention-retraction	0*	0.36	**	**	0*	0.65	**	1	0*	0.27	**	1
ton3 tongue tip elevation	0*	1	1	**	0*	0.65	**	1	0*	0.27	**	1
ton4 cupping-thinning	0*	1	1	**	0*	1	1	1	0*	1	1	1
ton5 thick bunched tongue	1*	1	1	**	1*	1	1	1	1*	1	0.63	1
ton6 transient/minimal protrusion	0	1	0.63	**	0	1	0.39	0.52	0	1	1	1
ton7 consistent/considerable protrusion	1	1	0.62	**	1	1	1	1	1	1	0.67	1
ton8 tongue protrusion between incisors	0	1	0.42	**	0	1	0.77	1	0	1	1	1
ton9 tongue protrusion beyond incisors	1	0.93	1	**	1	1	1	0.83	1	1	1	1
ton10 tongue thrust	1	0.93	1	**	1	1	1	1	1	1	1	1
ton11 asymmetry	1	0.93	1	**	1	1	1	1	1	1	1	1
Jaw												
jaw1 small vertical movements	0	1	1	1	0	1	1	1	0	1	1	1
jaw2 wid vertical movements	1	1	1	1	1	1	1	1	1	1	1	1
jaw3 jaw thrusting	1*	1	1	1	1*	1	1	1	1*	1	1	1
jaw4 jaw clenching	1	1	1	1	1*	1	1	1	1	1	1	1
jaw5 repetitive biting actions	1	1	1	**	1	1	1	1	1	1	1	1
jaw6 jaw alignment during swallow	0	1	1	**	0	1	0.47	1	0	1	0.63	1
jaw7 wide jaw excursions-swallow	1	1	1	**	1	1	1	1	1	1	1	1
jaw8 small jaw excursions-swallow	0	1	1	**	0	1	1	1	0	1	1	1
jaw9 combination of wide and small excursions	1	1	1	**	1	1	1	1	1	1	1	1
jaw10 external jaw stabilization-required 100%	1	1	1	**	1	1	1	1	1	1	1	1
jaw11 internal jaw stabilization	0	1	1	1	0	1	1	1	0	1	0.63	1
jaw12 external stabilization required 50% of time	1	1	1	1	1	1	1	1	1	1	0.63	1

Behavioral status: 0 = passed, 1 = failed.
*DOM behaviors not included in the final analysis.
**Indicates that there were too few ratable DOM behaviors to compute a kappa.

some of which have been shown to affect oral-motor functioning, our primary concern was the functioning of the oral-motor apparatus. We intend to carry out further analysis to assess the influence these may have had on oral-motor functioning; the results will be the subject of a future paper. OMC-6 (dried fruit) and OMC-1.4 (straw drinking) were omitted because they both contained large proportions of missing data and also had high proportions of nonratable responses. In such cases the children accepted the fruit but were unable to bite a piece off. In OMC-1.4 (straw drinking) they were able to create sufficient suction to move the liquid in the straw but they could not draw the liquid up into

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Table 8. Functional units—bottle, trainer cup, cup

	Bottle				Trainer cup				Cup			
Functional areas	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability	Behavioural status	Kappa stage 1	Kappa stage 2	Test-retest reliability
Reactivity												
react1 head orientation to teat/spout, etc	0	1	1	1	0	1	1	1	0	0.93	1	1
react2 anticipatory mouth opening	0	1	0.62	1	0	1	1	1	0	0.93	1	1
react3 increase in tension	1	1	1	1	1	1	1	1	1	0.93	1	1
react4 immediate removal of liquid	1	1	1	0.67	1	1	1	1	1	0.93	1	1
react5 no liquid enters mouth	1	1	1	1	1	1	1	1	1	0.93	1	1
Acceptance												
accept1 accepted within 2 sec	0*	0.93	1	1	0*	1	1	0.57	0*	1	1	1
accept2 time taken to accept food (>2 sec)	1	1	0.85	1	1	1	1	0.85	1	1	1	1
Initiation												
init1 sequence initiated within 2 sec	0*	1	1	1	0*	1	1	0.73	0	0	1	1
init2 time taken to initiate sequence (>2 sec)	1	1	1	1	1	0.78	1	1	1	0.85	0.93	0.78
init3 numerous attempts to sequence	1*	1	1	0.5	1	1	1	0.78	1*	1	0.63	0.75
init4 no. of attempts to initiate sequence-motor movements	1*	1	0.45	0.5	1	1	0.38	0.6	1*	1	0.45	0.56
Drooling/Liquid loss												
loss1 consistent/considerable drooling	1*	1	0.42	1	1*	1	1	1	1*	1	0.73	0.46
loss2 asymmetrical	1*	1	1	1	1*	1	1	0.82	1*	1	1	0.47
Sequencing												
seq1 smooth rhythmic sequence	0	1	1	1	0*	1	1	0.71	0	1	0.53	1
seq2 panic reactions	1	1	1	1	1	1	1	1	1	1	1	1
seq3 choking	1	1	1	1	1	1	1	0.54	1	1	1	1
Swallowing												
swal1 jaw alignment	0*	1	0.63	1	0	1	0.46	1	0*	1	1	1
swal2 lips closed during swallow	0*	1	0.43	1	0	1	0.3	0.61	0*	1	0.63	0.6
swal3 increase in tension	1*	1	0.63	1	1*	1	1	1	1*	1	1	1
swal4 panic reaction	1*	1	1	1	1	1	1	1	1*	1	1	1
swal5 no swallow observed	1*	1	1	1	1	1	1	1	1*	1	1	1
swal6 uses gravity/head extension	1*	1	0.63	1	1	1	0.56	1	1*	1	1	1
swal7 numerous attempts to initiate swallow	1*	1	1	1	1	1	0.47	1	1*	1	1	0.75
swal8 nasal regurgitation	1*	1	1	1	1*	1	1	1	1*	1	1	1
swal9 gagging	1	1	1	1	1*	1	1	1	1	1	1	1
swal10 vomiting	1	1	1	1	1	1	1	1	1	1	0.63	1
swal11 can stop sip/suck/swallow sequence	0	1	0.42	1	0*	1	1	1	0	1	0.63	1

Behavioral status: 0 = passed, 1 = failed.
*DOM behaviors not included in the final analysis.
**Indicates that there were too few ratable DOM behaviors to compute a kappa.

over 18 months of age

the mouth. McDonald's straws were used, equivalent to "adult" length with a wide bore. Children of this age can normally suck fluids from such a straw. Only the hard bite cracker (oatcake) was included in the final analysis for OMC-5 as this was considered the most challenging. Both the soft and medium cracker had greater amounts of missing data.

Discussion

The results of this study show that the SOMA is a reliable and comprehensive assessment of infant oral-motor func-

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tion. The schedule takes approximately 15–20 min to administer; the simple scoring system makes it an attractive tool for both clinical and research use. In order to develop effective treatment protocols and to evaluate the efficacy of their programs, therapists need such objective measures which are standardized for normal developmental function [17].

Five oral-motor challenge categories (OMC1–5) were included in the final version of the SOMA; recent research has highlighted the important influence texture has on the oral-motor performance of young children [19]. Dried fruit (OMC-6) was found to be too challenging for the majority of infants aged 12–18 months, although some as young as 12 months were able to bite and tear a piece off and masticate it satisfactorily. Similarly, the large proportion of data missing from the trials involving drinking from a straw (OMC1.4) indicated that the majority of infants less than 18 months of age were unable to successfully manage this task.

Certain discrete behaviors in the functional area, tongue movements and functional unit, and swallowing proved difficult to rate; for example, tongue tip elevation and lateral tongue movements were often not easily observed because the lips were closed. There is controversy about the age at which lateral tongue movements emerge. For example, Gisel et al. [59] suggested that only 7% of 2-year-old children were proficient in transfering food from side to side, but Morris [42] would support the view that lateral tongue movements can be observed as early as 6 months. We attempted to rate four types of lateral tongue movements (see Table 4). Such movements were not easily observed, but we did occasionally find the most mature form, side-to-side transfer, in children as young as 12 months. The rather wide age discrepancy reported in the literature could be related to the lack of consistent methods of assessment (which include the standardized administration of a variety of textures). Most researchers would agree that the emergence of such movement patterns are texture dependent. The presence or absence and degree of tongue protrusion were considerably easier to rate as they usually occurred in association with incomplete lip closure during a sucking, munching, or chewing cycle.

The discrete oral-motor behaviors that occurred during swallowing were the most difficult to record accurately, and are the subject of a subsequent investigation on the reliability of rating swallowing events in young children [10] (Reilly et al., unpublished data). At times it was impossible to tell from observation alone if and when a child had swallowed at all, although if there was a significant degree of associated oral-motor dysfunction with coughing and choking, the latter behaviors could be rated reliably. In our opinion it is impossible to evaluate swallowing in this age range by observation alone. Splaingard et al. [60] have shown that there is poor correlation between the bedside evaluation of swallowing and videofluroscopy.

Refusing to be fed was relatively common among infants in the 12–18-month age range who are beginning to develop some independence in self-feeding. Refusal behaviors can be affected by the texture presented and the presence or absence of any feeding difficulties. We found that the oral-motor challenge category affected the refusal rate; refusals were highest for the spooned solids and dried fruit textures, and lowest for the liquids (bottle, trainer-cup, cup, and straw drinking) and medium cracker. Many studies of oral-motor functioning fail to mention refusal rates despite the fact that this would seem to be a relatively common occurrence in infants. The relatively high rate for puree may be due to the fact that puree was the first texture administered and, had we randomly administered the textures, this may have been reduced.

Reliability of an instrument will vary according to the population on whom that instrument is being assessed [see 6]. The reliability figures presented here are applicable to a sample of non-neurologically impaired infants; children with cerebral palsy were excluded from those analyses. However, equivalent reliability studies on that sample were made separately and similar findings were obtained (data available from authors).

This study has shown that the majority of oral-motor behaviors can be reliably rated, even though a limited number of behaviors were not easily observed. Structured clinical evaluation schemes [e.g. 42, 44, 46] often include behaviors we have identified as not reliably ratable, such as tongue movements and swallowing. These behaviors are repeatedly mentioned in the literature as being problematic in children with oral-motor dysfunction but the value of including oral-motor behaviors in a clinical evaluation that cannot be easily observed or reliably rated is questionable. The SOMA has been shown to be a reliable instrument with established criteria for dealing with missing data. The validation of the instrument and its application to clinical groups is discussed in the accompanying paper.

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Appendix

Purée/Semisolid/Solid (from the SOMA Administration Manual-sample page)

General Points:

The examiner presents 3 trials of each food to the child.

The food must not be overloaded on the spoon, ie, a moderately sized teaspoonful-not heaped.

Procedure:

The examiner presents the loaded spoon to the child in the horizontal plane and in alignment with the child's mouth. The spoon is then withdrawn by at least 10–18 inches before the next trial presented.

If the child does not orientate/towards the spoon/open mouth or shows signs of accept/refusal, the spoon is kept in this position for 10 seconds before being withdrawn.

Problems:

- *the child does not open his/her mouth*
- *the child does not open his/her mouth far enough for the spoon to enter*
- *the child does not react in any way to food in his/her mouth—ie, the mouth may be already open lazily*
- *the child bites firmly on the spoon*

Additional information:

The food must not be scraped off onto the child's upper teeth or lips or any sensory cues given to the child to indicate its presence in the child's mouth.

The spoon must be drawn in a horizontal plane and not tilted either upwards or downwards. The second or third teaspoon is not presented until the child has completely emptied his/her mouth.

The examiner administers the fourth trial at the end of 3 trials.

REACTIVITY (from the SOMA Scoring Manual-sample page)

HEAD ORIENTATION TO FOOD	The infant moves his/her head, body or trunk towards the spoon or drink. This movement may involve trunk or head extension or a variety of other movements. This movement should be carefully checked in slow motion on the video.
ANTICIPATORY MOUTH OPENING	As a result of the spoon, food or drink approaching the infant's mouth opens in order to accept the food. In order to score present the child must fully open both the lips and the mandible. However, different degrees of 'wideness' are acceptable.
INCREASED TENSION	As a reaction to the food, etc. approaching there is a noticeable increase in body tension. Either the head or neck or both may tense. The whole body may show changes in tension or it may be restricted to one part.
FOOD REMOVAL	Although the examiner has been able to present the food to the child, the child immediatly removes it or expels it.
NO FOOD ENTERS THE MOUTH	The food is presented to the child but may not be kept in the mouth because: 1. The child is not able to bite a piece of biscuit, etc. off and therefore there is no chewing, etc. 2. The loaded spoon is presented and placed in the child's mouth but no food remains there because of poor lip actions or poor presentation by the examiner of the child has its mouth habitually open. 3. The child wants the food/drink but perhaps because of poor adaptive skills he/she cannot, for example, tip the cup/bottle up to obtain the drink.

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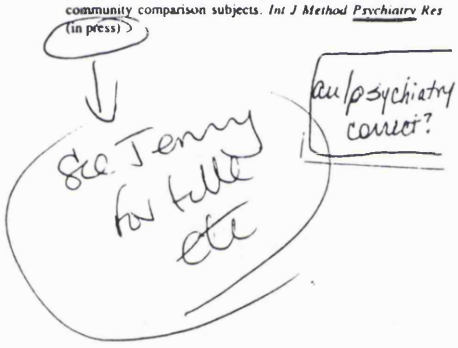

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Dysphagia

Schedule for Oral-Motor Assessment (SOMA): Methods of Validation

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Abstract. The Schedule for Oral Motor Assessment (SOMA) was developed for the purpose of objectively rating the oral-motor skills of preverbal children, with a view to identifying areas of deficient abilities that could have clinical significance. The instrument can be administered without special equipment, by a trained observer. Oral-motor function is assessed across a range of food textures and fluids. Ratings of oral-motor skills are largely made post hoc by analysis of a videorecording of the test administration. The test-retest and interrater reliability of the instrument have been shown to be excellent. Criterion validity was investigated by means of a novel 'seeded cluster analysis' procedure in which 127 young children were assessed, most of whom were between 8 and 24 months of age. Ten percent of the sample had known abnormal oral-motor function in association with cerebral palsy (ages between 12 and 42 months). Not only was criterion validity satisfactorily established by the analysis but an abbreviated version of the SOMA—suitable for screening purposes—was developed. This has been shown to have a positive predictive validity greater than 90% and sensitivity greater than 85% for the detection of infants with clinically significant oral-motor dysfunction.

Key words: Dysphagia — Oral-motor skills — Feeding — Infancy — Assessment.

The accurate description of feeding behaviors in young children requires the development of a system for objectively rating a complex set of interrelated motor skills. To be of clinical value, such an assessment system must be shown to be reliable and valid. The issue of reliability can be addressed from both the ratings made of discrete oral-motor behaviors (e.g., lip closure) which may be regarded as corresponding to a molecular level of analysis, and also at an aggregated, molar, or functional unit level (e.g., child shows dysfunction in tongue movements or biting ability). At each of these levels reliability should be considered first in terms of the repeatability of the child's behavior; test-retest reliability seeks to find, for example, whether the child shows tongue tip elevation on each of two trials of food presentation. Secondly, reliability can be measured in terms of whether independent observers would agree on the rating of that behavior on the same occasion. This is interrater reliability and asks, for instance, "Was tongue tip elevation scored by each observer?"

The development of a method for evaluating the feeding behavior in infants (Schedule for Oral Motor Assessment—SOMA) and the schedule's interrater reliability at the level of discrete oral motor behaviors has been described by Reilly et al. [1]. In that companion paper the reliability of scoring the SOMA was established and two sets of kappa coefficients on interrater agreement were presented, giving information about whether each discrete oral motor skill was ratable or not and, if ratable, whether two independent observers could agree if the child passed or failed a test of competence in that skill. Other behaviors were rated for their presence or absence according to whether they were developmentally appropriate. It was found that for judgments about whether the behavior was ratable at all (e.g., whether the skill in question could be clearly observed) there was excellent interrater reliability (i.e., kappa greater than 0.75) for 83% of discrete oral-motor skills. For judgments about whether the child passed or failed on each test of oral-motor skill, the results showed that 62% of

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behaviors could be scored by trained observers with this excellent level of interrater reliability. The SOMA has therefore been shown to have satisfactory reliability.

The issue of the validity of an assessment procedure, whether the assessment agrees with some external criterion, is in many ways more complex. Good reliability is a necessary but not sufficient condition for good validity. As with reliability, it is possible to establish validity at a number of levels, from the molecular to the more molar or aggregated attributes of behavior. In the terminology adopted for the analysis of the SOMA, the molecular level corresponds to discrete oral-motor skills, whereas the more molar attributes are termed functional units of behavior. It may be easier to establish validity or reliability at some levels of aggregation than others. For example, we have found that it is often difficult to obtain good interrater reliability at the level of the functional unit. Even experienced clinicians cannot always agree with one another when asked to rate whether units of oral motor function (e.g., a child's biting skills, in general) are abnormal or not. Nevertheless, they may agree quite well with one another when asked to make such judgments at the level of discrete behaviors (e.g., whether a controlled sustained bite is present).

The justification for developing a procedure such as the SOMA is precisely to move beyond relatively subjective clinical judgments of whether a child's oral-motor skills at an aggregated level of analysis are normal or abnormal and to provide a more high fidelity and objective basis for global judgments, on the basis of reliable ratings of individual oral motor behaviors. We were guided in the development of this instrument by the assumption that precise descriptions of both discrete oral motor skills and of functional units of aggregated behavior would be valuable in guiding treatment. However, during the development phase, where our discussions centered on how the SOMA should be validated, we concluded that there were no well-established norms by which decisions regarding the performance of a child's oral motor skills as abnormal or normal, at an aggregated level, could readily be made. Very few data are available on the development of oral motor skills in non-neurologically impaired children.

We decided to validate the SOMA at a molar level, and by means of a creative approach to data analysis aimed to see whether there existed patterns or profiles of scores which would conform to a novel independent criterion of abnormality. Such an analysis clearly requires a two-stage procedure. The first step is to identify and objectively record individual profiles of oral motor behavior. The second is to establish agreement by means of some external criterion. The approach adopted here represents a combination of these two stages. It entails the application of cluster analysis to our data, a well-established technique for identifying subgroups, within a heterogenous sample, that show a relative similar profile of scores. Data were from a sample of 127 children, including infants who had nonorganic failure to thrive (NOFT), normally developing infants (as a control group), and a small sample of children with cerebral palsy (CP). Statistical analyses were all undertaken using SPSS-PC, version 4.0.

We included children from these three groups in the validation procedure for a number of reasons. The NOFT infants and controls were intended to provide a standardization sample, a large group of children with relatively normally developing oral motor skills. We also had good reason to anticipate from the results of previous research that the NOFT group would include a substantial minority of children with immature or possibly deviant skills. The CP children were included as criterion subjects who were likely to show abnormal oral motor behaviors on the basis that they were selected because of overt feeding difficulties in association with neurological impairment.

By applying cluster analysis to the SOMA scores of all these children, pooled together, it was possible to identify subjects within the NOFT and control groups who showed deficiencies in their oral-motor difficulties which were similar to those found in the children with CP. In this sense the children with CP acted as a "seed" for the cluster analysis, by providing abnormal profiles of oral motor skills with which some of the other children could cluster. So far as we are aware, the deliberate use of a group with known pathology within the cluster analysis of a broader, largely undifferentiated group is novel; it will be referred to here as a "seeded cluster analysis."

The data from the CP children were used as validating criteria in two ways. First, the cluster analysis was applied to data from each of a series of seven oral motor challenges (OMC categories) separately. OMCs have been described in some detail in the accompanying paper [1]. There were seven OMC categories: puree, semisolids, solids, cracker, and liquid from a bottle, trainer cup, and cup. The interpretation of the cluster solution for each OMC category was as follows. The designation of which cluster (or clusters) comprised children with largely abnormal oral motor skills was based on the number of CP subjects in each cluster. By this means, for each OMC category one or at the most two abnormal clusters were identified. Secondly, on the basis of the cluster solution obtained from the analysis of SOMA data for each OMC category, individual children could obtain a score of 0 or 1, depending on whether they were or were not a member of one of those abnormal clusters. The total number of categories (maximum seven) for which a child was in an abnormal cluster could then be computed. This was one way of providing a severity, or abnormality,

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score for each child in the analysis, across the whole range of OMC categories on the SOMA. It was to be expected, if the validation exercise worked out, that the CP children would obtain significantly higher abnormality scores than either the control or the NOFT subjects.

Materials and Methods

Subjects

The data from 127 subjects were used for the purpose of analysis. They comprised 56 children with NOFT (aged between 12 and 18 months), 58 comparison children (matched for age), and 13 children with CP. The selection of the NOFT subjects is described in detail in Skuse et al. [2]. They were identified in the course of a prospective whole population survey of all births in an inner city within one calendar year. Comparison children were for the most part recruited during the same investigation. The subjects with CP were identified from attenders at specialist clinics within the Greater London area; selection criteria included age (less than 42 months) plus clinically significant oral motor dysfunction. Further details of this sample are given in Reilly and Skuse [3].

Procedures

For each subject, the following OMC categories have been used: puree, semi-solids, solids, cracker, liquid—bottle, liquid—trainer cup, and liquid—cup [1]. The standard administration of the SOMA requires the OMC to be presented to the child on three occasions (trials 1–3), following which the child is allowed a self-feeding attempt (trial 4). Initially, discrete oral-motor skills were coded separately for trial 1 and trial 3 only, but there were a substantial amount of missing data. Some oral-motor skills were rarely observed clearly; for that and other reasons, some children had data on just one of their four trials coded for an OMC category. The cluster analysis procedure we used requires list-wise deletion of cases with missing data, so if a child had any missing data at all (even just one variable) he or she would have had to have been excluded from the analysis altogether. Because we had a relatively large quantity of missing data, it was important to prevent a drastic reduction in sample size through list-wise deletion.

The initial step we took to counter this problem was to identify any discrete oral motor behaviors not observed in a large number of children. These individual variables were not ratable with sufficient frequency to warrant their inclusion in further analysis of skills associated with that OMC category; they were excluded altogether. This had to be done separately for each OMC category because the amount of missing data for any one skill or behavior varied considerably across categories. The discrete oral-motor behaviors that were entered into the cluster analysis for each OMC category are listed in Table 1.

The next step in dealing with missing data concerned the discrete behaviors listed in Table 1. Children had been administered three trials on each OMC category, plus a self-feeding trial when appropriate. If a child had missing data for any particular behavior on trial 1 the child's score for trial 3 was substituted. If the child had missing data on trials 1 and 3, the observation on trial 2 was substituted and, failing that, trial 4. This was a conservative procedure insofar as our aim was to identify abnormality, and it was considered the most appropriate way of dealing with missing data for the NOFT and control groups. Trials 2 and 4 were not separately analyzed. However, many of the CP subjects' "missing data" were accounted for by their failure to cope with the feeding task. They were often unable to take the food into their mouths because of oral motor or postural problems, or neurological difficulties during the trial. For that reason, where data were not available for the CP subjects because they were observed to be unable to cope with the challenge due to deficient oral motor skills, the trial was coded as "failed."

Analysis

By the joint use of these procedures for reducing missing data, it was possible to maintain the sample size at 127 for all foodstuffs. Discrete oral-motor behaviors entering the cluster analysis for each OMC category comprised the series of binary scores (pass/fail). The basis on which individual behaviors were scored as pass/fail is given in Reilly et al. [1]. Cluster analysis was used to identify relatively homogenous clusters of children, i.e., children who tended to show similar profiles in terms of their oral-motor skills, when challenged with particular foodstuffs. Ward's method was used to identify the clusters, and the squared euclidian distance between children was used as the dissimilarity metric. Children with very different profiles of scores would accordingly be measured as distant from one another. Ward's method identifies which children and clusters are closest to one another, and then groups them in increasingly larger conglomerates at each step in the analysis. The process begins with individual children being treated as though they were in completely separate and unique "clusters." That is to say, there are initially as many clusters as there are subjects entering the analysis. As the clustering proceeds, children are allocated to progressively larger and larger groups, or clusters, until eventually all of the subjects in the analysis are in the same single cluster. Because of the way in which the analysis proceeds, step by step, it is known as "hierarchical agglomerative clustering." Just two children or clusters are merged at each step; therefore, with a sample size of 127 there are 127 sequential steps in the procedure.

It is a matter of judgment which cluster solution is taken to be the most appropriate for the analysis in question. After inspection of the dendrograms produced by Ward's method we decided to confine our attention to solutions from the final stages of analysis, which produced one to six clusters. The best cluster solution was one that took into account cluster sizes in successive groupings, the index of distance between clusters, and the distribution of the CP children across clusters. It was desirable to have as many of the CP children as possible in just one cluster.

On the basis of the above procedure, a 5-cluster solution was finally selected as the basis for further analysis, for each OMC category. The first stage in the interpretation of the clusters was to inspect their characteristics in terms of the discrete oral-motor behaviors that were used to derive them. The proportions of children within each of the five clusters, obtained from the analysis of individual OMC categories, who had failed on each discrete oral-motor skill, were summarized and tabulated.

Consider the data in Table 2. This shows some of the discrete oral-motor behaviors that were entered into the analysis for the OMC category "puree"; 45 variables were entered (16 are listed) and the five cluster solution is reported. The figures shown on this table are percentages of children within each cluster who failed each oral-motor skill that was entered into the analysis (details in Table 1). For example, "sequence 3" refers to whether or not the child was observed to choke or gag while ingesting puree. "Failure" means that behavior was observed. We see that none of the children in cluster 1 failed on that item (for puree) but 88% of the children in cluster 5 did so. At this stage of the analysis all the items where at least 30% of the children in a cluster had failed the oral-motor skill in question were highlighted. The decision about what constituted failure was a clinical judgment about individual oral motor skills on the basis of the glossary for the SOMA, on which reliable judgments were indeed possible. What normal children in the

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Table 1. Oral-motor behaviors entering cluster analysis for each foodstuff

	Puree	Semi-solids	Solids	Cracker	Bottle	Trainer cup	Cup
react1							
react2							
react3							
react4							
react5							
accept1		•			•	•	•
accept2	•		•	•			
loss1							
loss2	•	•	•	•			
drool1					•	•	•
drool2			•		•	•	•
sequence1						•	
sequence2				•			
sequence3				•			
initiation1					•	•	•
initiation2	•	•	•	•			
initiation3					•		•
initiation4					•		•
lip1					•	•	•
lip2					•	•	•
lip3							
lip4							
lip5	•	•	•	•			
lip6	•	•	•	•			
lip7							
lip8							
lip9							
lip10							
lip11							
lip12							
lip13	•		•	•			
tongue1	•	•	•	•	•	•	•
tongue2	•	•	•	•	•	•	•
tongue3	•	•	•	•	•	•	•
tongue4	•	•	•	•	•	•	•
tongue5	•	•	•	•	•	•	•
tongue6		•	•	•			
tongue7		•	•	•			
tongue8		•	•	•			
tongue9		•	•	•			
tongue10							
tongue11							
tongue12							
tongue13							
tongue14			•	•			
tongue15			•	•			
jaw1							
jaw2							
jaw3					•	•	•
jaw4						•	
jaw5							
jaw6							
jaw7							
jaw8							
jaw9							
jaw10				•			
jaw11							
jaw12							
jaw13	•						
swallow1	•	•	•	•	•		•

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	Puree	Semi-solids	Solids	Cracker	Bottle	Trainer cup	Cup
swallow2	•	•	•	•	•		•
swallow3	•	•	•	•	•	•	•
swallow4	•	•	•	•	•		•
swallow5	•	•	•	•	•		•
swallow6	•	•	•	•	•		•
swallow7	•	•	•	•	•		•
swallow8		•		•	•	•	•
swallow9		•					
swallow10		•		•			
swallow11		•		•		•	
swallow12				•	•		•
bite1							
bite2							
bite3							
bite4							
bite5							
bite6							
bite7							
bite8							
bite9							
bite10							
bite11							
bite12							

Shading indicates that the DOM behavior was entered into the cluster analysis for that foodstuff;
•Indicates that the DOM behaviour was not entered into the cluster analysis for that foodstuff. Blank boxes indicate the DOM was not applicable to the OMC category.

Table 2. Preliminary five-cluster solution for puree: % of children in each OMC category who "failed" oral-motor skill

	Cluster 1 (n = 27)	Cluster 2 (n = 24)	Cluster 3 (n = 34)	Cluster 4 (n = 35)	Cluster 5 (n = 7)
React1	4	0	12	**37**	**72**
React2	0	0	3	23	0
React3	4	0	0	11	29
React4	0	0	3	0	14
React5	0	4	0	0	14
Accept1	11	0	12	23	**86**
Accept2	4	0	9	9	**57**
Foodloss1	7	0	9	17	**71**
Foodloss2	0	0	3	0	0
Drool1	0	0	9	**43**	**100**
Drool2	0	0	0	3	**43**
Sequence1	0	0	0	0	**29**
Sequence2	**44**	0	**22**	20	**57**
Sequence3	0	0	0	3	**88**
bite1	7	**100**	3	0	**86**
....	....	....	....	....	....
Bite12	0	1	0	0	**29**

Items for which ≥30% of subjects failed the oral-motor skill are in boldface. The proportions of all 45 behaviors entering the analysis that were failed by at least 30% of cluster members were cluster 1, 9% (4 items); cluster 2, 2% (1 item); cluster 3, 9% (4 items); cluster 4, 31% (14 items); cluster 5, 55% (25 items).

age range were expected to achieve was based upon the results of testing a considerable number of them during pilot investigations. A cutoff of 30% distinguished, in most cases, just one or two clusters that contained a high proportion of cluster members (usually many more than 30%) who failed the oral-motor skill in question.

The 45 individual behaviors that entered into the analysis for puree were therefore examined carefully; it is clear from the data presented in Table 2 that the proportion of behaviors that were failed by at least 30% of subjects varied considerably from cluster to cluster. The figures range from just 1/45 (2%) behaviors for the members of cluster 2

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Table 3. The relationship between OMC categories, their constituent oral-motor skills, and the designation of clusters as abnormal during preliminary analysis

OMC category	Numbers of discrete behaviors rated in category	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Puree	45	4 (9%)	1 (2%)	4 (9%)	**14 (31%)**	**25 (55%)**
Semisolids	45	4 (9%)	11 (24%)	3 (7%)	**24 (53%)**	**40 (89%)**
Solids	44	4 (9%)	1 (2%)	**15 (34%)**	**39 (89%)**	3 (7%)
Cracker	48	4 (8%)	1 (2%)	**35 (73%)**	8 (18%)	**45 (94%)**
Bottle	37	0	4 (11%)	**26 (70%)**	**11 (30%)**	**18 (49%)**
Trainer cup	44	**36 (82%)**	4 (9%)	13 (29%)	11 (25%)	2 (4%)
Cup	37	8 (22%)	2 (5%)	1 (3%)	**21 (57%)**	**14 (38%)**

Figures presented are the numbers (proportions) of all discrete behaviors entering the cluster analysis that have been failed by at least 30% of each cluster membership. For example, 14/45 (31%) of the oral-motor skills entering the analysis for puree were failed by more than 30% of the members of cluster 4. Because a *high* proportion of this cluster's members failed a *wide* range of skills, the cluster, which has been designated "abnormal," is highlighted. Clusters represent behaviors rather than individual children.

to 26/45 (58%) behaviors for the members of cluster 5. Evidently the members of cluster 5 have a far wider range of abnormal oral-motor skills when presented with purees than the members of clusters 1 or 2.

This exercise was repeated for each of the OMC categories. On the basis of the proportion of all discrete oral-motor behaviors relevant to that category that were failed by >30% of subjects (within each of the five clusters), it was possible to make a ranking of their "abnormality." On the basis of these proportions, it was possible to designate one or two clusters the "abnormal" clusters for each OMC category (see Table 3). Table 3 should be interpreted as follows. Take the finding for puree, for example; there were 45 discrete behaviors entered into the cluster analysis. Considering just those 45 discrete behaviors, varying proportions of subjects failed each one of them, within each cluster, as was shown in Table 2. Moving now from subjects to behaviors we can see that for any one cluster, varying proportions of all oral-motor skills *rated (within each OMC category) were failed in this way (Table 3)*. If a high proportion of cluster members failed a high proportion of the skills being tested then that cluster could, we concluded, be considered abnormal. It is clear with respect to, say, cluster 5 under "cracker," that no less than 94% (45/48) of the individual behaviors entering the analysis were failed by at least 30% of the members of that cluster. Consequently, we could regard cluster 5 as an abnormal cluster. The proportion of behaviors relevant to the OMC category that had to be failed in order to designate an individual cluster as abnormal was taken to be >30%.

It was also possible, considering the data presented in Tables 2 and 3 together, to decide which discrete oral-motor skills were failing to provide a reasonable level of discrimination between clusters and so would be better dropped altogether. For example, in Table 2 Init1 sequence initiated within 2 sec of food presentation did not provide any useful discrimination between clusters 2 and 5, although as the figures presented in Table 3 make clear, cluster 2 was a "super-normal" collection of subjects, and cluster 5 was the most abnormal cluster of all.

We could now begin to validate the cluster analysis by seeing the extent to which the ranking of individual clusters corresponded to their composition of subjects. The hypothesis was that the normal and super-normal clusters should contain normal comparison subjects, and that the most abnormal clusters should contain a high proportion of the children who had CP and known oral-motor difficulties (Tables 4–10). These tables show the number of subjects who belonged to the three

Table 4. Cross-tabulation of cluster membership (diagnostic categories) by rank position of abnormality

Puree	Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
	1	Normal	3	5	21	1
	2	Normal	1	12	12	0
	3	Normal	2	14	20	0
	4	Abnormal	4	24	5	6
	5	Abnormal	5	1	0	6

Table 5. Cluster membership

Semisolids	Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
	1	Normal	1	8	23	0
	2	Normal	3	22	12	2
	3	Normal	2	11	19	2
	4	Abnormal	4	4	0	8
	5	Abnormal	5	11	4	1

Table 6. Cluster membership

Solids	Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
	1	Normal	3	13	14	0
	2	Normal	1	17	21	1
	3	Abnormal	4	10	5	7
	4	Abnormal	5	10	5	4
	5	Normal	2	6	13	1

Table 7. Cluster membership

Cracker	Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
	1	Normal	2	15	21	1
	2	Normal	1	17	23	4
	3	Abnormal	4	11	10	2
	4	Normal	3	13	4	2
	5	Abnormal	5	0	0	4

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Table 8. Cluster membership

Bottle	Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
	1	Normal	1	23	17	1
	2	Normal	2	23	37	0
	3	Abnormal	5	5	2	6
	4	Abnormal	3	4	1	5
	5	Abnormal	4	1	1	1

Table 9. Cluster membership

Trainer cup	Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
	1	Abnormal	5	12	6	2
	2	Normal	2	15	11	2
	3	Normal	4	23	24	5
	4	Normal	3	2	0	0
	5	Normal	1	4	17	4

Table 10. Cluster membership

Cup	Cluster	Qualitative descriptor	Rank	NOFT	Comparison	CP
	1	Normal	3	25	14	9
	2	Normal	2	15	22	0
	3	Normal	1	13	15	1
	4	Abnormal	5	3	6	2
	5	Abnormal	4	0	1	1

clinical groups, i.e., NOFT, comparisons, and CP, and the distribution of those subjects across the 5 clusters, for individual OMC categories. Adding up the figures in the columns, the totals will give the number of children tested within each of those clinical groups who were entered into the analysis for that OMC category, i.e., 56 NOFT subjects, 58 comparisons, and 13 children with cerebral palsy. Abnormal clusters have been defined as described in Table 3.

These figures could be interpreted in a number of different ways. Perhaps the simplest approach would be to look at the proportion of children within each cluster who fall into the CP category and match these to the rank position of the cluster's abnormality score. We would expect to find those clusters with the largest proportion of discrete behaviors "failed" (i.e., the highlighted cluster from Table 3) to have the greatest proportion of members with CP. To take as an example puree in Table 4, the most normal cluster (2) has no CP member, whereas in the most abnormal (5), 86% (6/7) of the members have CP.

Considering the data presented in Tables 4–10, it is clear that the extent to which the children with CP appear within the clusters designated "abnormal" varies considerably between individual OMC categories. These data are summarized in Table 11. The clusters shown on Table 3 have been amalgamated, so that there are now effectively just 2 clusters for each OM category, a large normal cluster and a smaller abnormal cluster. If our categorization has been successful, and the SOMA yields valid data, it should be possible to show reasonably good discrimination between control children, who were normal in terms of their oral-motor skills, and the CP children who were by definition "abnormal" in a high proportion of their skills.

The figures presented in Table 11 show that excellent discrimination was obtained on the basis of the 45 behaviors that entered into the analysis for puree, and it was also good for solids, semisolids, and liquid from a bottle. Look at the first row, which corresponds to challenging the children with puree. Only 1 out of the 13 children with CP fell into a normal cluster (see also Table 4), yet 91% of the comparison children were entirely in normal clusters. In contrast, cracker provided rather less discrimination between the groups because over half the children with CP (54%) fell into normal clusters, although only 17% of comparisons were placed in abnormal clusters. Neither the trainer cup nor the cup seem to present particular difficulties for children with CP, a surprising finding.

The figures in Table 11 show a consistently higher proportion of children with NOFT (mean 24.6%) than comparisons (mean 11.3%) in abnormal clusters. A former pilot survey found that a substantial proportion of infants with NOFT had clinically significant oral-motor dysfunction [4]. Details of the characteristics of the children with NOFT and oral-motor dysfunction will be presented elsewhere (Skuse et al., unpublished data).

In order to gain a more general picture of how each child functioned in terms of OM skills across the OMC categories, it was possible to count each time one of them appeared in an abnormal cluster. A child's individual abnormality score could therefore range from 0 to 7 (7 being the total number of OMC categories); this was a further test of the validity of the SOMA procedure. The mean score of the children in the CP group was 4.23, that of the children in the comparison group was 0.79, and that of the children who were failing to thrive 1.71 ($F = 42.43$, $df = 2,124$, $p < 0.0001$). Using Scheffé's procedure, all three means were found to be significantly different from one another at $p < 0.05$.

Screening Procedure

A final stage in the data analysis was to develop a simple screening procedure that could be adopted by other researchers and clinicians, in

Table 11. The number and percentage of children from each subject group who fell into amalgamated normal and abnormal clusters on the basis of their oral-motor skills

OMC category	NOFT		Comparisons		CP	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
Puree	31 (55%)	25 (45%)	53 (91%)	5 (9%)	1 (8%)	12 (92%)
Semisolids	41 (73%)	15 (27%)	54 (93%)	4 (7%)	4 (31%)	9 (69%)
Solids	36 (64%)	20 (36%)	48 (83%)	10 (17%)	2 (15%)	11 (85%)
Cracker	45 (80%)	11 (20%)	48 (83%)	10 (17%)	7 (54%)	6 (46%)
Bottle	46 (82%)	10 (18%)	51 (93%)	4 (7%)	1 (8%)	12 (92%)
Trainer cup	44 (79%)	12 (21%)	52 (90%)	6 (10%)	11 (85%)	2 (15%)
Cup	53 (95%)	3 (5%)	51 (88%)	7 (12%)	10 (77%)	3 (23%)

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Table 12. Cluster membership showing proportions (%) of members of individual clusters failing a subset of discrete oral-motor skills

	Puree				
	Abnormal clusters			Normal clusters	
	Cluster 5	Cluster 4	Cluster 3	Cluster 2	Cluster 1
React1	72	37	12	0	4
Accept1	86	23	12	0	11
Food loss	57	9	9	0	4
Seq1	100	43	9	0	0
Seq2	43	3	0	0	0
Init1	57	20	22	0	44
Init3	88	3	0	0	0
Init4	86	0	3	100	7
Lip1	86	91	12	1	11
Lip2	86	83	21	1	7
Lip3	100	100	29	1	30
Lip4	14	40	15	1	0
Lip8	100	77	91	1	0
Lip9	100	34	9	1	100
Lip10	100	86	50	1	19
Lip11	100	71	6	1	11
Lip12	100	94	74	1	63
Tongue10	86	6	41	1	0
Tongue11	29	46	6	1	0
Tongue12	86	31	24	1	0
Jaw1	86	46	15	1	15
Jaw2	86	17	0	1	0
Jaw3	86	9	0	1	0
Jaw9	86	3	3	1	7
Jaw10	71	9	0	1	4
Jaw11	43	3	0	1	0
Jaw12	43	3	0	1	0

Variables that discriminate both clusters 4 and 5 from all other clusters: R1(React1), R10(Sequence 1), R16(Lip1), R17(Lip2), R18(Lip3), R24(Lip11), R27(Tongue11), R28(Tongue12), R32(Jaw1).

order to determine, with a fair degree of confidence, whether a child's pattern of oral-motor skills on any particular oral-motor challange was normal or abnormal, and hence would demand further investigation. In order to achieve this, it was necessary to identify those behaviors that contributed maximally to the normal/abnormal cluster distinction within each OMC category (Table 11).

Consider the data in Table 12. This shows a restricted set of twenty-five out of the total number of 45 discrete oral-motor skills rated on presentation of puree. The choice of which restricted sets of oral-motor skills were appropriate for this tabulation was based upon the proportion of all discrete behaviors entering the cluster analysis that were failed by at least 30% of the cluster membership. Considering the figures presented in Table 3, we see that 25 of all 45 behaviors were failed by at least 30% of the members of cluster 5. Accordingly, these 25 behaviors should be the most discriminating for the purpose of developing an abbreviated screening procedure.

Table 12 is in part a representation of the data from Table 2. As was shown in Table 3, for puree, clusters 4 and 5 were considered abnormal and they were amalgamated for the purpose of the analysis presented in Table 11. Visual inspection of Table 12 allows us to see that the nine discrete skills—React1, Seq1, Lip1, Lip2, Lip3, Lip11, Tongue11, Tongue12, and Jaw1 tend to be failed by the members of clusters 4 and 5, but are passed by all the members of the other three clusters. The interpretation of these abbreviations can be found in Appendix A.

An individual child who is suspected of having deficient oral-motor skills can therefore be tested and a provisional abnormality score given for functioning on puree, on the basis of a test of just these nine discrete behaviors. If the child fails all nine skills, the maximum score of 9 would be obtained. We have called this the "total dysfunction score." If this were to be an efficient way of screening for abnormality, we would expect to find that child in an abnormal cluster in Table 11.

Table 13. Relationship between total dysfunction scores obtained by individual children (puree only) and cluster membership

Total dysfunction score	Abnormal clusters		Normal clusters		
	Cluster 4	Cluster 5	Cluster 1	Cluster 2	Cluster 3
0	0	0	13	24	9
1	0	0	8	0	11
2	1	0	5	0	11
3	2	0	1	0	0
4	7	0	0	0	3
5	7	1	0	0	0
6	9	0	0	0	0
7	6	1	0	0	0
8	2	5	0	0	0
9	1	0	0	0	0

The analysis included 127 children. Their distribution between clusters is shown, according to the total dysfunction score they obtained. For example, 5 children in cluster 5 obtained a total dysfunction score of 8.

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Table 14. Efficiency of the screening procedure in predicting abnormal group membership

OMC category	Predicted group membership	Actual group membership		Positive predictive value	Sensitivity
		Abnormal	Normal		
Puree	Abnormal	41	4	0.98	0.91
	Normal	1	81		
Semisolid	Abnormal	25	8	0.78	0.89
	Normal	3	91		
Solid	Abnormal	38	2	0.95	0.93
	Normal	3	84		
Cracker	Abnormal	27	0	1.0	1.0
	Normal	0	100		
Bottle	Abnormal	26	1	0.96	0.96
	Normal	1	99		
Trainer cup	Abnormal	20	0	1.0	1.0
	Normal	0	107		
Cup	Abnormal	10	1	1.0	1.0
	Normal	0	117		

Table 15. Discrete oral-motor behaviors used in the screening procedure, for individual OMC categories

Puree	Semisolid	Solid	Cracker	Bottle	Trainer cup	Cup
React1	Drool1	Food loss	Food loss	React2	Liquid loss	Tongue7
Sequence1	Sequence1	Drool1	Drool	React4	Sequence2	Tongue9
Lip1	Init3 Initiation 3	Sequence1	Init3 Initiation 3	Accept2	Sequence3	Tongue10
Lip2	Lip13	Lip1	Lip4	Lip3	Tongue10	Tongue11
Lip3	Jaw1	Lip2	Lip7	Lip5	Tongue11	Jaw1
Lip11	Jaw2	Lip4	Lip9	Lip6	Jaw1	Jaw2
Tongue11	Jaw3	Lip11	Tongue10	Lip7	Jaw6	Jaw4
Tongue12	Jaw10	Tongue10	Tongue11	Jaw1	Jaw10	Jaw6
Jaw1		Jaw1	Tongue12	Swallow1	Jaw12	Swallow9
			Tongue13		Swallow5	
			Jaw2		Swallow6	
			Jaw3		Swallow7	
			Jaw4			
			Jaw5			
			Jaw8			
			Jaw9			
			Jaw11			
			Jaw12			
			Swallow9			
			Bite5			
Cutting score 3 or more	Cutting score 4 or more	Cutting score 4 or more	Cutting score 11 or more	Cutting score 5 or more	Cutting score 15 or more	Cutting score 5 or more

The key to the interpretation of the codes presented in this table is found in Appendix A.

At the other extreme, we would expect to find a child whose total dysfunction score was zero in a normal cluster. Evidently, for each OMC category there should be a cut off point, scores above which would predict membership of an abnormal cluster, and scores below which would predict membership of a normal cluster. The scores obtained by the members of the five clusters for the OMC category puree are given in Table 13.

The effectiveness of the screening procedure in predicting group membership could now be established for each of the OMC categories. In the case of purée, children with total dysfunction scores ≥3 would be graded as "probably abnormal" and those with scores ≤2 would be designated "probably normal." This cutting score value will vary for the different OMCs for at least two reasons. First, because the OMC categories relate to different ranges of behaviors. The variety of skills needed to cope with a firm solid, such as a cracker, is greater than the skills necessary to ingest puree, therefore there are more observed oral-motor behaviors that might be rated abnormal. Secondly, some OMC categories were relatively undiscriminating (e.g., trainer cup; see Table 9), therefore a wider range of behaviors must be rated in order to achieve reasonable diagnostic efficacy. The positive predictive value of a high score can be calculated (i.e., the proportion of children with high scores who are members of an abnormal cluster), and so can the sensitivity of the test procedure (i.e., the proportion of all those children who were members of an abnormal cluster for puree who obtained total

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Appendix A.

Puree	
react1	head orientation to spoon/teat
sequence1	smooth rhythmic sequence
lip1	lower lip draws inwards around spoon
lip2	upper lip removes food from the spoon
lip3	lower/upper lip assists in cleaning
lip11	lower lip active during suck/munch/chew
tongue11	consistent./considerable protrusion
tongue12	protrusion beyond incisors
jaw1	graded jaw opening
Cutting score of 3 or more	

semisolids	
drool1	consistent/considerable drooling
sequence1	smooth rhythmic sequence
initiation3	numerous attempts to sequence
lip13	lips closed during swallow
jaw1	graded jaw opening
jaw2	internal jaw stabilisation
jaw3	external jaw stabilisation required 100%
jaw10	associated jaw movements
cutting score 4 or more	

solids	
food loss	less than 25% of food lost
drool1	consistent/considerable drooling
sequence1	sequence initiated within 2 seconds
lip1	lower lip draws inwards around spoon
lip2	upper lip removes food from spoon
lip4	lower lip behind upper teeth/sucking
lip11	lower lip active during sucking/munching/chewing
tongue10	transient minimal tongue protrusion
jaw1	graded jaw opening
cutting score 4 or more	

cracker	
food loss1	profuse/marked food loss
drool1	profuse/marked drooling
initiation3	numerous attempts to sequence
lip4	lower lip behind upper teeth to suck
lip7	lips close around stimulus during bite
lip9	lips closed intermittently during suck/chew/munch
tongue10	transient/minimal tongue protrusion
tongue11	consistent/considerable tongue protrusion
tongue12	protrusion beyond incisors
tongue13	protrusion beyond lips
jaw2	internal jaw stabilisation
jaw3	variable stabilisation (not fully established)
jaw4	external stabilisation
jaw5	vertical movements
jaw8	wide vertical excursions
jaw9	small vertical excursions
jaw11	associated head movements to bite
jaw12	uses fingers to transfer food
swallow9	gagging
bite5	controlled sustained bite
bite8	graded jaw opening
bite12	mouths cracker only
cutting score 9 or more	

dysfunction scores of 3 or more). These values are given in Table 14. The simple screening procedure was obviously highly effective in identifying children who, the cluster analysis suggested, had abnormal oral-motor skills. Remember, because we did not make decisions about the functional integrity or efficiency of individual children's oral-motor skills on a clinical basis, the validation we performed was not done on the basis of clinical judgments about those children, other than the fact that the children with CP were chosen because they had grossly abnormal oral-motor skills. The technique we developed here was designed to move the validation process of this screening instrument beyond the somewhat tautological use of a global clinical impression, at a molar level of analysis, to a sophisticated combination of applied clinical skills and statistical analysis of discrete skills which were independent of molar judgments.

With the exception of semi-solids, the positive predictive value of the scoring procedure is in each case greater than 90% (Table 14). When evaluating a screening procedure, equal weight should be given to the proportion of true cases missed, i.e., false-negatives. As Table 14 indicates, this was consistently less than 10%, with the exception of semi-solids.

As was mentioned above, it should be recognized that the efficiency of the screening procedure has been evaluated on the same sample from which the original abnormal groups were identified. It is therefore to be expected that this procedure would show a lower degree of efficiency on an independent sample of children. It would be of considerable interest to establish whether the SOMA, when scored using the above subset of behaviors and using the given cutting points, could accurately differentiate between other independent groups of children with and without oral-motor dysfunction.

The variables used to compute sensitivities and positive predictive validities, for each OMC category, are listed in Table 15, together with the cutting points above which a child would be designated as probably abnormal on the basis of deficient oral-motor skills. The interpretation of the abbreviations given on the table can be found in Appendix A.

In conclusion, the SOMA is an instrument that can be administered relatively simply by a trained observer, such as a speech pathologist. It has been designed to detect minor degrees of oral-motor dysfunction in preverbal children. Preliminary enquiries soon revealed the fact that there was little consensus among clinicians about what developmentally appropriate skills would be observed in children between 12 and 18 months of age. There was even less agreement about what patterns of deficiencies in skills would indicate significant oral-motor dysfunction. Accordingly, the criterion validity of the SOMA was established by means of novel statistical procedures whereby children who had confirmed grossly deficient oral-motor skills, in association with cerebral palsy, were entered into a cluster analysis together with a large number of apparently normal subjects, a substantial minority of whom were nevertheless at risk. A number of different methods by which criterion validity was established with this sample have been

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trainer cup	
liquid loss2	profuse/marked liquid loss
sequencing2	panic reactions when liquid presented
sequencing3	choking
tongue10	tongue thrust
tongue11	asymmetry
jaw1	small vertical movements
jaw6	jaw alignment during drinking
jaw10	external jaw stabilisation 100%
jaw12	internal jaw stabilisation
swallow1	jaw alignment
swallow4	panic reactions
swallow5	no swallow observed
swallow6	uses gravity eg: head extension
swallow7	numerous attempts to initiate swallow
cutting score of 5 or more	

cup	
tongue7	consistent considerable protrusion
tongue9	tongue protrusion beyond lower lip
tongue10	tongue thrust
tongue11	asymmetry
jaw1	small vertical movements
jaw2	wide vertical movements
jaw4	jaw clenching
jaw6	jaw alignment
swallow9	gagging
cutting score 5 or more	

bottle	
react2	anticipatory mouth opening
react4	no liquid enters mouth
accept2	accepts liquid within 2 seconds
lip3	firm contact around teat/nipple ∠ lip
lip5	intermittent/incomplete lip closure ∠ lip
lip6	intermittent/incomplete lip closure ∠ lip
lip7	lips closed during swallow
jaw1	small vertical movements
sequencing1	smooth rhythmic sequence
cutting score 5 or more	

presented. The abbreviated list of oral-motor behaviors shown in Table 15 should direct clinicians towards specific skills that could be used for screening purposes, when faced with a preverbal child who is suspected of having oral-motor difficulties.

The screening instrument should be applicable to a wide range of ages, from those who have just been introduced to mixed feeds (minimum age of 6 months) to those who are totally independent feeders with a maximum appropriate age in normal children of about 2 years. In children who are developmentally retarded, the upper age limit is determined largely by the extent of the subject's handicap; the instrument should be perfectly suitable for assessing the oral-motor skills of children whose developmental abilities in general are equivalent to a chronological age of 6 months to 2 years.

In order to prepare a full report of oral-motor abilities across the entire range of food textures, a formal training in the application and scoring of the Schedule for Oral Motor Assessment would be required.

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CHARACTERISTICS AND MANAGEMENT OF FEEDING PROBLEMS OF YOUNG CHILDREN WITH CEREBRAL PALSY

Sheena Reilly
David Skuse

Many infants with cerebral palsy are small relative to age-standardised norms, for reasons that are not fully understood. The more severe their neurological condition, the poorer their growth. Several investigators have shown that there is a positive correlation between short stature, motor dysfunction and degree of mental retardation (Ruby and Matheny 1962, Mosier *et al.* 1965, Hammond *et al.* 1966, Culley and Middleton 1969).

Impaired self-feeding skills (Tobis *et al.* 1961), especially if associated with oral-facial involvement (Krick and Van Duyn 1984), may exacerbate growth retardation of children with cerebral palsy. Some researchers believe that inadequate nutritional intake resulting from feeding difficulties is likely to be the main cause (Ruby and Matheny 1962, Shapiro *et al.* 1986). Boyle (1991) states that poor growth has too often been ascribed to underlying neurological deficits or inactivity rather than to chronic malnutrition.

The reasons why children with cerebral palsy have difficulty achieving a nutritional intake sufficient to sustain a normal rate of growth have been summarised as follows (Lancet 1990): communication difficulties that inhibit or distort requests for food; impaired expression of hunger or food preferences; lack of self-feeding skills; inability to forage; and severe degrees of oral-motor dysfunction. Additional complications include aspiration of food (Griggs *et al.* 1989) and gastro-oesphageal reflux, which is believed to affect up to 75 per cent of these children (Rempel *et al.* 1988).

On the basis of observations of patients over two years of age being fed by a nurse in hospital, Gisel and Patrick (1988) concluded that children with cerebral palsy took up to 15 times longer than neurologically intact children of the same weight to eat a mouthful of food. Johnson and Deitz (1985) were told by mothers of children with cerebral palsy that they spent up to seven hours a day feeding them. Such protracted periods meeting basic needs would mean that less time was available for other joint activities, and disorders of parent-child relationships could develop as a result (Johnson and Deitz 1985, Boyle 1991).

To date there have been no home-based observational studies of the mealtime routines and behaviour of infants with cerebral palsy, which could discover whether the observations of Gisel and Patrick (1988) were representative, and could test the validity of parental reports. The aim of this preliminary survey was to study the eating patterns of a small sample who were at high risk of disordered feeding on account of oral-motor dysfunction, and to describe the normal feeding practices of their usual caregiver in their own homes.

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Subjects and method

Preschool children with cerebral palsy and a clinically significant degree of oral-motor dysfunction were identified from attenders at specialist clinics within the Greater London area. The clinics specialised in seeing young children with cerebral palsy, and they were contacted with a view to identifying a sample (under 42 months of age) who had clinically significant oral-motor dysfunction, not necessarily associated with known feeding difficulties.

The 12 children selected were all seen at home with their mothers. They ranged in age from 15 to 39 (mean 19·5) months. Anthropometric measures from birth, including weight, length and head circumference, were obtained from hospital and health clinic records. The children's medical histories, diagnosis and the results of any developmental assessments were recorded.

A comparison group of children, matched pair-wise according to age, sex and race, was also investigated. This group was selected from a large sample of children who had been seen during a previous study of infant feeding practices. The use of a weight-age matched comparison group was considered (Gisel and Patrick 1988), but more than half of our case children had weight-ages ranging from three to six months, so it would not have been appropriate to compare measures such as dietary intake, feeding practices and oral-motor performance with normal infants matched to this age-range.

A semi-structured feeding interview was conducted with all mothers; it included questions about past and present feeding practices (Reilly *et al.* 1989). Details were taken of the children's feeding difficulties and any intervention relating to them, as well as of their mother's feelings about the availability of treatment and advice. We were particularly interested in any intervention within the first 12 months after birth.

The child's main meal of the day was observed and video-recorded. Mothers were asked to feed their children as they usually did, and written notes were made of the types and amounts of food offered to and eaten by the child at this meal. It was not our purpose to undertake a weighed dietary assessment; accordingly, quantities were estimated on the household measures principle (Bransby and Wagner 1945, Nettleton *et al.* 1980). Particular note was made of any food lost through dribbling, spillage or spitting out. In addition, the interviewer completed a 24-hour dietary recall with each mother, using household measures to estimate quantities offered to and consumed by the child (Fehily 1983). Dietary data were analysed using Diet2000 (B & W Electronics 1987), a computer programme based on McCance and Widdowson's figures on the composition of foods (Paul and Southgate 1978).

The child's seating position and the availability of specialised equipment such as adaptive seating devices, special spoons or cups were noted, as well as any specific routines used during feeding. The Feeding Assessment Schedule (FAS; Reilly *et al.* 1987, Mathisen *et al.* 1989) was administered and video-recorded in order to assess the degree of oral-motor dysfunction. The FAS entails the presentation of three trials of a variety of tastes and textures—purée, semi-solids, solids and liquids. Ratings of oral-motor function are almost all based on analysis of the video-recordings, supplemented by some on-the-spot ratings of behaviours that could not be seen easily on video-film.

Statistical analyses

Because the children were matched pair-wise, where dependent variables comprised interval scales (*e.g.* caloric intake) or continuous scales of measurement (*e.g.* anthropometry), paired *t* tests were used (Cohen and Holliday 1982). Categorical variables, such as those relating to feeding difficulties, were dichotomised (*i.e.* present/absent) and between-group comparisons were made using the McNemar test (see Altman 1991).

Results

Table I gives details of the case children's ages at assessment, diagnosis, birthweight, gestation and anthropometric details. There were no significant differences in the case and comparison children's birthweights, gestations or ages at assessment.

TABLE I
Characteristics of children with cerebral palsy

Case	*Age (mths)*	*Diagnosis*	*Additional neurological deficit*	*Performance level (Griffiths 1970)*	*Gestation (wks)*	*Standardised birthweight†*	*Wt/age (z scores)***	*Lth/age (z scores)***	*Wt/lth (z scores)***
1	16	Spastic quadriplegia	Epilepsy, partial vision	4 mths	39	+1·21	−0·88	−2·40	+0·64
2	23	Dystonic cerebral palsy	Squint	11·5 mths	42	−0·83	−1·95	−0·93	−1·95
3	16	Hemiplegia	Squint, ? mild high-frequency hearing loss	17 mths	28	+0·98	−2·26	−1·98	−1·66
4	18	Spastic quadriplegia	Sensorineural hearing loss, nocturnal seizures	4 mths	39	0·00	−3·18	−2·85	−2·33
5	17	Spastic quadriplegia	Severe hearing loss (cochlear malformation), ? vision	3 mths	36	+1·53	−2·74	−3·55	−0·84
6	19	Hypotonic cerebral palsy	Epilepsy	—	40	−0·88	−0·92	−0·44	−0·89
7	15	Spastic quadriplegia	Squint	6 mths	29	+1·48	−3·17	−3·04	−2·11
8	26	Spastic quadriplegia	Blind, epilepsy	—	40	−0·58	+0·97	+2·62	−0·20
9	39	Spastic quadriplegia	Partial sight	3 mths	40	+0·56	−1·42	−1·19	−0·86
10	16	Spastic quadriplegia	—	—	40	−1·07	−3·41	−2·45	−3·12
11	16	Spastic quadriplegia	—	MDI <50* PDI <50*	39	+0·49	−2·36	−1·31	−1·93
12	15	Spastic quadriplegia	—	9·5 mths	30	+0·81	−2·25	−0·66	−2·06

*One child not tested on Griffiths Scales; score for Bayley Scales given (Bayley 1969).
**z-score is a standardised normal deviate. Probabilities under various parts of the normal distribution of weight, length and weight for length can be summarised by an age-independent measure. For example 15·9 per cent of a population are more than one z-value below the mean (50th centile), 2·3 per cent are more than two z-values below the mean.
†Birthweights standardised for gestation, sex and ordinal position and expressed as z scores (Tanner and Thomson 1970).

Feeding histories

Similar proportions of mothers in both groups began to breast-feed their infants (eight case, seven comparison group). However, six case group mothers discontinued breast-feeding by nine weeks because of poor, slow or weak sucking, difficulty latching onto the nipple or pushing it out with the tongue, and concern because milk tended to dribble out of the baby's mouth. Others were worried about excessive coughing and choking. There were significantly more difficulties with early sucking ($p<0·001$) and swallowing ($p<0·01$) among the case infants. When case mothers introduced bottle-feeds, similar problems were encountered, especially in encouraging the children to suck on the teat and in finding a satisfactory feeding position. Three mentioned that bottle-feeds seemed worse than breast-feeds, as their babies 'choked more'. A particular difficulty was finding a satisfactory teat of the appropriate size, flow and shape.

In contrast, five of the seven comparison group mothers were able to breast-feed beyond nine weeks, and reported a smooth transition from breast to bottle-feeding.

There was no significant difference in the age at which solid foods were introduced to the case infants (mean 16, SD 4·3 weeks) and comparison infants (mean 15, SD 5·9 weeks), although case mothers reported significantly more problems, especially when introducing lumpy foodstuffs ($p<0·001$); and there

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TABLE II
Dietary intakes (kcal) of case and comparison infants

	Case *Mean (SD)*	*Comparison* *Mean (SD)*	*p**
24-hour recall	804·0 (249·7)	1282·75 (659·9)	<0·05
Mealtime observation			
Food offered	214·6 (108·8)	343·6 (103·1)	<0·005
Food consumed	149·0 (78·2)	271·6 (107·6)	<0·005

**t* test for related samples.

was significantly more coughing ($p<0·001$), choking ($p<0·005$) and gagging ($p<0·001$). Most case group mothers said their infants were unable to bite ($p<0·001$) or chew solid foods ($p<0·005$) and that these symptoms had persisted: as a result they were unwilling to allow anyone else to undertake the feeding. All case group mothers said their child had had serious episodes of vomiting during the first 12 months, and for nine children this problem had persisted ($p<0·005$). Vomiting was not reported as a problem for any comparison child.

Mealtime observations

Eight of the comparison children were seated appropriately in high-chairs, two sat on the sofa and two alternated between sitting and walking around while eating. All case infants had been provided with special seats or modifications to existing high-chairs or baby-chairs, but only six of the 12 were placed in them. Instead, they were fed in a variety of positions and situations, including semi-reclined on their mother's lap, propped up with cushions or lying on a sofa. Some mothers found the equipment a 'nuisance' and time-consuming; for example they claimed it was considerably easier and quicker to feed their child on the sofa, rather than 'struggle' to position the child in the recommended chair. In one case the adapted seat was too small, and the chair was so poorly designed that the mother would have only been able to feed her child at eye-level by lying prone on the floor.

A group of experienced paediatric physiotherapists were asked to rate the adequacy of each case child's position during mealtimes from the videotapes. Six children were rated as poorly positioned, three as adequately positioned and three as well positioned.

The children's mealtimes were timed from the presentation of the first mouthful of food to when the mother signalled the meal was over. There was no significant difference in the duration of the case (mean 18′ 14″, SD 9′ 44″) and comparison mealtimes (mean 17′ 40″, SD 7′ 36″). In the case group, durations ranged from 5′ 54″ to 36′ 45″, and in the comparison group from 8′ 05″ to 30′ 50″. All children had a regular pattern of three main meals a day, with an occasional interim snack or drink. All mothers described the video-recorded mealtimes as typical. The most striking feature of the case group mealtimes was the lack of verbal interaction, the children being fed in a very mechanical manner. A remarkable change took place in the mother's behaviour at the conclusion of the meal, however, when there was a marked increase in the verbalisations directed at and in attention paid to the child, suggesting that the quality of their interaction might be impoverished only at mealtimes.

Dietary measures

Table II shows the results of the dietary measures. Case children were both offered and consumed less food than the comparison children during the observed mealtimes. They also were reported to consume significantly less food over a 24-hour period than the comparison group. Only two case children were fed family foods; the other 10 were given powdered baby foods, which could easily

TABLE IIIa
Oral-motor functioning: case infants

	Age (mths)	Mealtime duration	Food loss	Severity rating	Lip function		
					Removes food from spoon	Cleans lips	Lip-closure, suck/munch
1	16	36′ 45″	Moderate	Severe	–	–	–
2	23	32′ 28″	Moderate	Moderate	–	+	–
3	16	16′ 46″	Moderate	Moderate	–	+	–
4	18	19′ 36″	Severe	Severe	–	–	–
5	17	8′ 30″	Severe	Severe	–	–	–
6	19	11′ 38″	Moderate	Moderate	–	+	–
7	15	7′ 37″	Severe	Severe	–	–	–
8	26	17′ 56″	Severe	Severe	–	–	–
9	39	26′ 18″	Severe	Severe	–	–	–
10	16	21′ 05″	Severe	Severe	–	–	–
11	16	14′ 16″	Severe	Severe	–	–	–
12	15	5′ 54″	Moderate	Moderate	–	–	–

+ = present, – = absent.

TABLE IIIb
Oral-motor functioning: case infants

	Tongue function			Jaw function			Swallow			
	Extension, retraction	Elevation, depression	Lateralisation	Vertical	Lateral	Stabilisation	Delay	Gags	Cough, choke	Aspiration
1	+	–	–	+	–	–	+	–	+	–
2	+	+	–	+	–	–	+	+	–	–
3	+	–	–	+	–	–	+	–	–	–
4	+	–	–	+	–	–	+	+	+	+
5	+	–	–	+	–	–	+	+	–	+
6	+	+	–	+	–	–	+	–	–	–
7	+	–	–	–	–	–	+	+	+	+
8	+	–	–	+	–	–	+	+	–	+
9	+	–	–	+	–	–	+	–	–	–
10	+	+	–	+	–	–	+	+	–	–
11	+	+	–	+	–	–	+	+	–	–
12	+	+	–	+	–	–	+	+	–	–

+ = present, – = absent;

be mixed with water to achieve the desired texture. The diets of many of the case children therefore were restricted in both taste and texture, whereas the majority of the comparison children (10) tended to eat family foods, supplemented by some proprietary baby food ($p<0{\cdot}01$). The mother of the one especially well-nourished case child prepared small but calorically dense meals, using her knowledge as a dietitian. She also added caloric supplements to his food. Although he had severe oral-motor problems, and aspiration of foodstuffs was suspected, he was thriving.

Oral-motor functioning

Oral-motor functioning was rated almost entirely by analysis of the videotapes, apart from a small number of on-the-spot observations. No oral-motor abnormalities were detected in the comparison children. It was not possible to administer all the subtests of the Feeding Assessment Schedule to the case children; four had histories of coughing and choking on hard solids, so textures such as biscuits or dried fruit were omitted. Tables IIIa and IIIb summarise the oral-motor functioning of each case child for two of the food types presented, purée and semi-solid.

Further assessments

Interviewed about their personal response to mealtimes, eight case mothers said they were not an enjoyable experience, and six said they were currently having great difficulty in feeding their children. None

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TABLE IV
Mothers' mental state on GHQ subscales

Subscale	*Case Mean (SD)*	*Comparison Mean (SD)*	*p**
Social dysfunction	8·5 (2·6)	4·7 (2·4)	<0·05
Anxiety	6·8 (3·8)	3·9 (3·3)	NS
Depression	5·3 (4·4)	2·0 (3·7)	<0·05
Somatic symptoms	6·5 (2·9)	3·7 (2·1)	<0·05

**t* test for related samples.

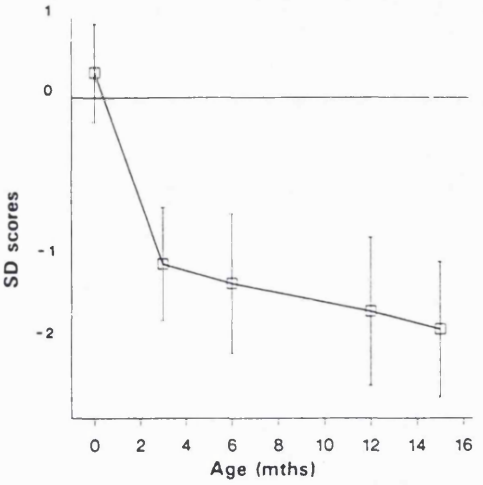

Fig. 1. Mean weight-gain trajectory (z scores) of 12 children with cerebral palsy. 95 per cent confidence intervals are shown.

of the comparison group mothers said they were having difficulties in feeding their children ($p<0·05$) and only one mother said mealtimes were not enjoyable ($p<0·05$). Asked whether they were confident they were giving their baby the right types of food, five comparison mothers but only one case mother (the dietitian) believed they were doing so. This was a non-significant difference. Six case and two comparison mothers did not feel they were giving their children appropriate foodstuffs; the remainder were unsure. Eight case mothers believed that their children were very slow eaters ($p<0·01$) and nine were worried that their children were not eating enough, nor growing fast enough. One comparison group mother had similar concerns ($p<0·05$). Asked to respond to the statement 'I hardly ever have time to sit and feed my baby', one case mother retorted 'it feels like that's all I ever do'.

Mothers were asked to complete the General Health Questionnaire (28-item version; Goldberg and Hillier 1979). This is a self-administered screening test designed to detect minor but clinically significant psychiatric disorders. 10 case and two comparison group mothers obtained scores above the recommended threshold of probable disorders when the conventional (0011) system of scoring was used, in which a maximum score of 28 could be obtained ($p<0·005$). Four subscales measuring dimensions of symptomatology can be derived, each of which has a maximum score of 21 when scored according to the 0123 method (Goldberg and Williams 1988). Significant differences were found on three of the four subscales: social dysfunction, depression and somatic symptoms (Table IV).

Five case mothers had received only minimal assistance in managing their child's feeding problem, and two were unaware that help was available. The other five case mothers had received some intervention from speech therapists, physiotherapists or occupational therapists. However, in almost all cases this was infrequent (once a month on average) and only three mothers were currently receiving advice. Only two mothers had been advised about appropriate nutrition by a dietitian or other professional. None of the comparison mothers had sought or been given professional advice about feeding their babies.

Growth patterns

Birthweights were standardised for gestation, sex, ordinal position, maternal height and, if available, mid-pregnancy weight (Tanner and Thomson 1970). Full correction for preterm birth was applied (Den Ouden *et al.* 1991). Weights after birth were converted into standard deviation scores (SDS) by the CDC anthropometric analysis system (Center for Disease Control, Atlanta), using the NCHS standards (Hamill *et al.* 1977). There was no significant difference in the

birthweights of the case (mean 0·31 SDS, SD 0·95) and comparison children (mean −0·67 SDS, SD 1·23). However, by 15 months the mean weight of the case infants was −1·89 SDS below the population mean, whereas that of the comparison infants was 0·11 SDS above the population mean. The mean growth-trajectory of the case children from birth to 15 months (the age of the youngest child seen) is shown in Figure 1. By 12 weeks their mean weight had fallen to −1·16 SDS (SD 1·4) and it continued to fall to −1·75 SDS (SD 1·36) at 12 months. By the age of 15 months, four of the case children had weights between 3 and 4 SDS below the population mean. Health professionals described several mothers as 'obsessed' with their child's weight. In the case of one child with chronic failure to thrive and a history of very severe feeding problems, it was stated that 'weight is only a problem for the mother'. A complicating factor was suspected aspiration of foodstuffs and gastric contents, as well as repeated upper respiratory tract infections.

Discussion

Mothers of young children with cerebral palsy and oral-motor dysfunction in this descriptive study reported considerably more difficulty in feeding their babies than did mothers of an age-matched comparison group. Many case group mothers said that feeding problems were the first indication they had had that something was wrong with their child. Commencing in several cases soon after birth, symptoms persisted throughout the first year of life and seemed to intensify when solid foods were introduced. Many of the case children were not referred for oral-motor assessment until they were almost 12 months of age, or even older. Their mean standardised birthweight was above the population mean, which is in contrast to the children studied by Blair and Stanley (1990) in their investigation of the intra-uterine growth of infants with cerebral palsy. The birthweights of the case and comparison groups were not significantly different. 10 of the children with cerebral palsy subsequently failed to thrive; their declining growth trajectories were noticeable within 12 weeks of birth, usually long before the diagnosis of cerebral palsy was made. Severe feeding difficulties were associated with faltering growth. None of the comparison group failed to thrive.

Skuse (1992) stresses the importance of adequate weight-gain in the first six months of life for later mental development; exceptionally poor rates of growth can be associated with predictable deficits in cognitive and psychomotor skills. Boyle (1991) suggested that nutritional care of developmentally disabled children is often overlooked during infancy.

A link between the severity of oral-motor dysfunction and poor growth has been proposed by a number of researchers (Tobis *et al.* 1961, Ruby *et al.* 1962, Krick and Van Duyn 1984, Shapiro *et al.* 1986). In the present study, nine of the children had severe and three had moderate oral-motor dysfunction. Gisel and Patrick (1988) suggested that in order to compensate for the potential detrimental effect of this oral-motor dysfunction on nutritional intake, daily feeding-times would need to be longer than normal waking hours. Indeed, several studies have suggested that the mothers of disabled children must spend a large proportion of their time feeding them (Johnston and Deitz 1985, Gisel and Patrick 1988). Our own observations, however, were that, despite most of the children having significant oral-motor dysfunction, their mealtimes were relatively brief: the duration did not differ significantly from that of the matched comparison group and they did not receive more frequent feeds. The dietary intakes of the two groups did differ significantly; the case children were both offered and consumed less food during the observed meal, and their mothers reported that they consumed less food over a 24-hour period. The majority of the case children were fed proprietary baby foods, which a recent report suggests are of relatively low caloric density (Lobstein 1991). Gisel and Patrick (1988) suggest that early quantitative assessments of feeding efficiency should be made in order to identify children who cannot be adequately nourished without ancillary feeding. Boyle (1991) described a comprehensive approach to the nu-

tritional management of the developmentally disabled child. He suggests that assessment of growth is the most suitable indicator of nutritional status and that aggressive nutritional therapy is indicated for any infant or child who is unable to take sufficient nutrition orally. Non-oral methods of feeding had not been considered as alternatives for any of the children in the present study, either to promote growth or to complement oral feeding.

A high level of probable psychiatric disturbance was found among the mothers we interviewed. 10 of the 12 case mothers (83 per cent), but only two comparison mothers (17 per cent), scored above the recommended threshold of the 28-item GHQ, compared with 41·1 per cent of women in the original validation study (Goldberg and Hillier 1979). Caring for a disabled child is well-recognised as a substantial source of stress and has been shown to be associated with maternal depression (Hirst 1985). Caretakers who feel socially isolated, stressed or depressed may be less able to provide effective nurture for their developmentally disabled child (Boyle 1991). The mothers in this study recounted what they perceived as the enormous burden of feeding their children, although objective measures showed that the children's mealtimes were relatively short. The lack of accuracy in reporting feeding times could be related to mental health; Moore *et al.* (1988) found that depressed individuals more often gave a general account rather than recalling the specific details of an event. In addition, they found that the cognitions of depressed people were likely to be dominated by relatively generalised representations of past events, rather than specific instances. Only two mothers had been offered support or counselling for psychiatric disturbance.

Conclusions

This exploratory study showed that failure to thrive was common among a small group of young children with cerebral palsy who had severe oral-motor dysfunction. Feeding problems usually had persisted since birth. Mealtime observations suggested that a combination of factors such as relatively brief mealtimes, poor positioning, severe oral-motor dysfunction and offering food of low caloric density may have been the cause.

As far as we are aware, no other study has directly observed and measured the time taken to feed children with cerebral palsy; our findings stress the importance of home observations as part of the assessment and management of children with feeding problems (Wolke and Skuse 1992). They also indicate the importance of a multidisciplinary approach in evaluating the feeding of such children, in which paediatrician, speech therapist, occupational and physiotherapist, dietitian and clinical psychologist co-ordinate their efforts to provide a comprehensive service to these families.

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Authors' Appointments
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SUMMARY

The nature and extent of feeding difficulties associated with cerebral palsy was assessed in 12 infants with moderate to severe oral-motor dysfunction, compared with a control group. Data were gathered at the infants' homes by interview and by direct observation of mealtimes. The results revealed a range of long-standing problems, for which little management advice had been given. Most case infants were poorly positioned; specially designed seats were not used. The mean duration of mealtimes for case and comparison infants did not differ significantly. Case infants ate and were offered less food than the control infants. Feeding problems usually had persisted since birth and were associated with marked failure to thrive. Multidisciplinary assessments of the severe feeding difficulties of these children are indicated.

RÉSUMÉ

Caractéristiques et prise en charge des problèmes d'alimentation chez les jeunes enfants présentant des troubles moteurs d'origine cérébrale

La nature et l'importance des difficultés d'alimentation associés à des troubles moteurs d'origine

cérébrale ont été appréciées chez 12 nourrissons présentant une dysfonction oro-motrice de modérée à sévère, et comparées avec un groupe contrôle. Les données ont été recueillies au domicile des nourrissons par entrevue et observation directe des repas. Les résultats ont révélés des problèmes variés et datant de longtemps, et pour lesquels peu d'avis avaient été donnés. La plupart des nourrissons étaient mal installés; les sièges spéciaux n'étaient pas utilisés. La durée moyenne des repas ne différait pas significativement entre index et contrôles. Les nourrissons index mangeaient moins et se voyaient offrir moins de nourriture que les contrôles. Les problèmes d'alimentation dataient habituellement de la naissance et étaient associés à une insuffisance d'évolution pondérale. Une évaluation multidisciplinaire des difficultés d'alimentation sévères chez ces enfants est indiquée.

ZUSAMMENFASSUNG

Charakteristika und Handhabung von Fütterungesproblemen bei Kleinkindern mit Cerebralparese

Bei 12 Kindern mit mittelschweren bis schweren oralmotorischen Funktionsstörungen wurden Art und Ausmaß von Fütterungsschwierigkeiten im Zusammenhang mit einer Cerebralparese untersucht und mit einer Kontrollgruppe verglichen. Die Daten wurden bei den Kindern zu Hause durch Interview und direkte Beobachtung der Mahlzeiten erhoben. Die Ergebnisse zeigten eine Reihe von lange bestehenden Problemen, für die wenig Hilfen zur Handhabung gegeben worden waren. Die meisten Kinder waren schlecht gelagert, Spezialsitze wurden nicht verwendet. Die mittlere Dauer der Mahlzeiten zeigte bei Patienten und Kontrollen keinen signifikanten Unterschied. Die Patienten aßen weniger und bekamen weniger angeboten als die Kontrollen. Die Ernährungsprobleme bestanden in der Regel seit der Geburt und waren von erheblichen Gedeihstörungen begleitet. Die schweren Ernährungsprobleme bei diesen Kindern müssen dringend interdisziplinär untersucht werden.

RESUMEN

Caracteristicas y manejo de los problemas de alimentación en niños pequeños con parálisis cerebral

Se evaluó la naturaleza y extensión de las dificultades de alimentación asociados con la parálisis cerebral en 12 lactantes con disfunción motora oral, en comparación con un grupo control. Los datos fueron recogidos en los hogares de los lactantes por medio de entrevistas y por observación directa en las horas de las comidas. Los resultados revelaron un margen de problemas de larga duración, para lo cuales se habian dado muy pocos consejos terapéuticos. La mayoría de los niños problema estaban mal colocados, no utilizando ningún tipo de asientos especiales. No habia diferencia significativa en el promedio de duración de las comidas entre los niños problema y los control. Los niños problema comían menos y se les ofrecía menos comida que los controles. Los problemas de alimentación se mantenian desde el nacimiento e iban asociados a un marcado fallo del desarrollo. Se indican valoraciones multidisciplinarias de las dificultades de alimentación en tales niños.

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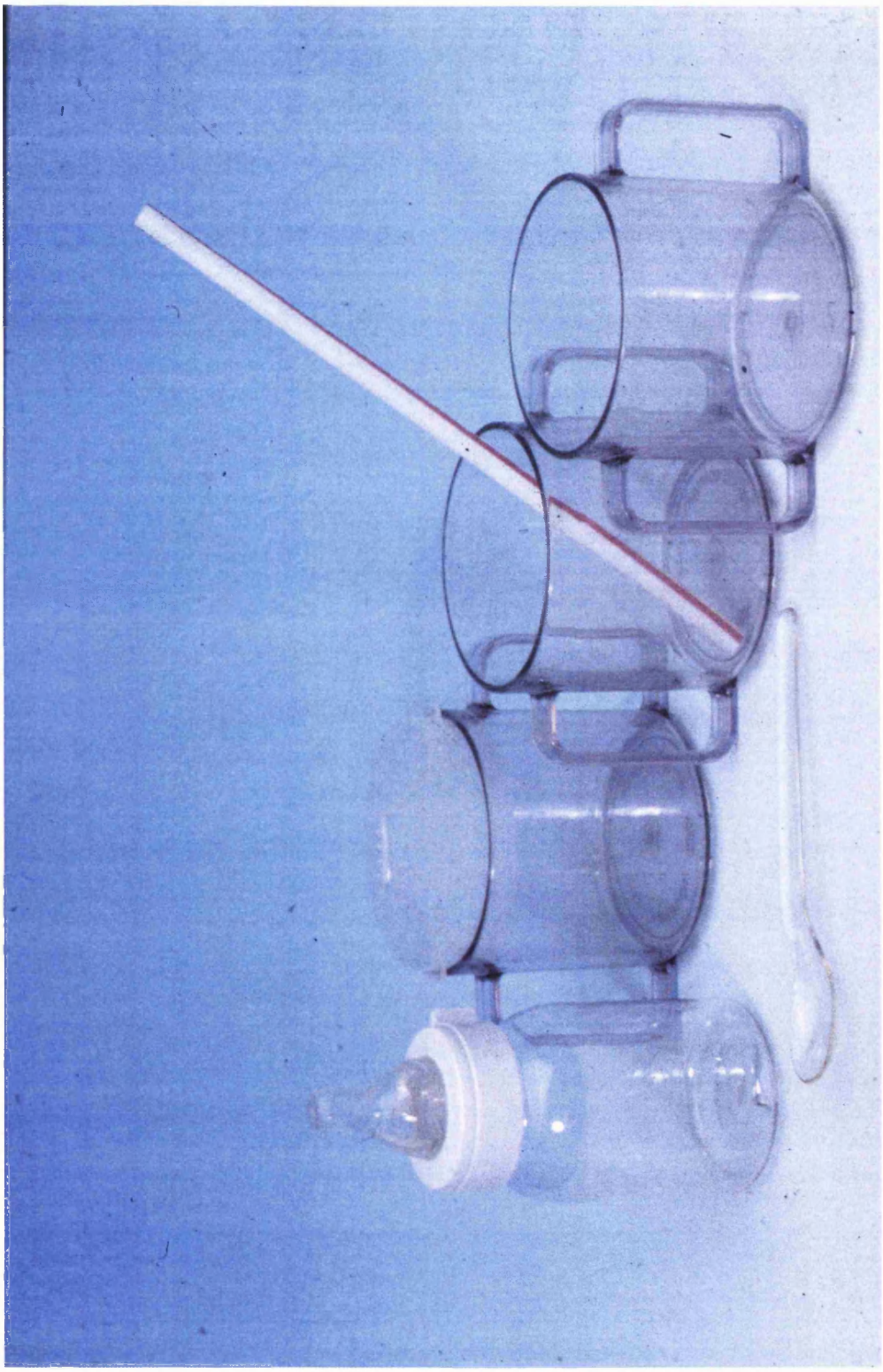
Appendix 2

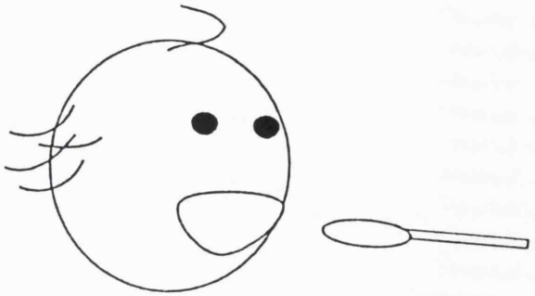


Appendix 3

S.O.M.A.

Schedule for Oral Motor Assessment

Administration Procedures



TM

Liquids

Bottle

It is important to ascertain if the child still uses or ever has used a bottle.

The bottle is placed on the tray or given to the child to hold.

Only if the child makes no attempt to hold it or pick it up does the examiner present the bottle and align it with the child's mouth.

The examiner allows the child to drink from the bottle as much or as little as he/she desires.

The examiner keeps the bottle in position until the child indicates withdrawal by stopping sucking or pushing the teat away.

If the child stops sucking and keeps the teat in his/her mouth the examiner keeps the bottle in position.

Problems

- *The child may never have drunk from a bottle or no longer use a bottle.*
- *The child may be used to a different bottle or teat and prefer his/her own.*

Trainer cup

The cup is placed on the tray or in the child's hands.

Only if the child makes no attempt to pick up or hold the cup does the examiner present the spout of the trainer cup aligned with the child's mouth (after 10 seconds).

Cup

As for trainer cup.

Contents:

What is the SOMA?

The SOMA is a standardised procedure for assessing oral-motor skills in infants.

It was developed by the South London Growth and Development Study team at the Institute of Child Health, London.

The team included:

Sheena Reilly, Research Speech Therapist
David Skuse, Consultant Child Psychiatrist
Dieter Wolke, Research Psychologist
Berenice Mathisen, Research Speech Therapist

Biscuit

The examiner offers the biscuit to the child by a) placing it on the table/tray (if possible) and drawing the child's attention to it, or b) placing it in the child's hand, or c) aligning it with the child's mouth if the child cannot hold the biscuit.

The biscuit is left in position (on tray/in child's hand/or held by examiner) for 10 seconds before being withdrawn.

Problems

- *Child does not pick up biscuit from tray/table - shows no interest in it.*
- *Action - examiner places biscuit in child's hand.*

- *i) Child plays with biscuit and makes no attempt to bite.*
- *ii) Child throws biscuit.*
- *iii) Child gives biscuit back to examiner.*
- *Action - if ii) or iii) - constitutes a trial and therefore a refusal if no reaction occurs within 10 seconds.*

The examiner then presents biscuit and aligns with child's mouth and continues with presentation for 10 seconds before withdrawing and re-presenting for Trial 2/3 etc.

The biscuit is presented in the horizontal plane and not at an upwards or downwards angle.

- *The biscuit must not be broken off against the child's teeth.*
- *The biscuit must be left in position until the child reacts in some way.*
- *No sensory cues such as touching the teeth must be given.*

The examiner keeps biscuit in position until the child manages to break off a piece.

The child is allowed to make as many attempts (perhaps unsustained or weak) on the biscuit as is necessary.

- *The biscuit is not represented for second or third trial until child has finished mouthful.*

Chewable solid - dried fruit

The child is given the dried fruit either in the hand or it is put on the tray/table. If the child makes no attempt to take the dried fruit himself the examiner presents the dried fruit to him (after waiting 10 seconds).

The dried fruit is presented in the horizontal plane and not at an upwards or downwards angle.

The dried fruit must not be broken off against the child's teeth.

The dried fruit must be left in position until the child reacts in some way.

No sensory cues such as touching the teeth must be given.

The examiner keeps dried fruit in position until the child manages to break off a piece.

The child is allowed to make as many attempts (perhaps unsustained or weak) on the dried fruit as is necessary.

The dried fruit is not represented for second or third trial until child has finished mouthful.

What does the SOMA entail?

The SOMA was developed initially as a research tool to summarise and quantify the oral-motor functioning of infants who had no major neurological disorder. It has since been further developed for use with a variety of children both with and without neurological disorders.

A variety of foods of different textures, graded from liquid to chewable solids are presented to the infant in a standard manner. There are 7 foodtypes ranging from liquids, purée, semi-solid and solid, soft, medium and hard biscuits and dried fruit.

A simultaneous video recording is made of the child's head and neck in order to record oral-motor performance.

The assessment takes approximately 20 minutes.

A detailed analysis is made of the child's oral-motor functioning from the video recording using standardised scoring procedures.

As a result a comprehensive assessment profile is obtained of the child's oral-motor functioning.

The SOMA has proved to be a useful and reliable tool currently being used in a variety of research projects investigating oral-motor functioning in infancy. Clinicians use it to obtain a useful baseline assessment, to plan treatment and measure progress.

Who uses the SOMA?

The SOMA is currently used by a variety of different professionals including speech and language therapists, physiotherapists, occupational therapists, psychologists and psychiatrists who have undergone all or part of the training course.

To date it has been used principally in the UK although we are in the process of setting up international links.

Purée/Semi-solid/Solid

The examiner presents 3 trials of each food to the child.

The food must not be overloaded on the spoon, ie, a moderately sized teaspoonful - not heaped.

The examiner presents the loaded spoon is presented to the child in the horizontal plane and in alignment with the child's mouth. The spoon remains in position for 10 seconds before being withdrawn if the child does not accept or orientate towards it or react in any way. Eg, rejection after 10 seconds the spoon is withdrawn by at least 10-18 inches before being re-presented.

Problems

- *The child does not open his/her mouth.*
- *The child does not open his/her mouth far enough for the spoon to enter.*
- *The child does not react in any way to food in his/her mouth - ie, mouth is open laxly.*
- *The child bites firmly on the spoon.*

The food must not be scraped off onto the child's upper teeth or lips or any sensory cues given to the child to indicate its presence in the child's mouth.

When withdrawn the spoon must again be withdrawn in a horizontal plane and the spoon not tilted either upwards or downwards. The second or third teaspoon is not presented until the child has completely emptied his/her mouth.

The examiner administers the adaptive skills procedure - see separate notes - at the end of 3 trials for each food type.

Trial 1 after purée
Trial 2 after semi-solid
Trial 3 after solid

What constitutes a trial?

A trial consists of the stimulus being presented to the child and remaining in the presentation position for 10 seconds before being withdrawn. The stimulus is withdrawn by at least 12-18 inches before being re-presented for a second trial.

How reliable is the SOMA?

Detailed inter-rater reliability studies have been completed on the SOMA and it has been found to be a very reliable instrument. Kappa ratings have been computed for each individual variable. The majority of their summary scores are in the 0.75 to 1.0 range indicating excellent agreement beyond chance. Further information is available from the trainer upon request.

Where can I be trained?

Training is available at the Institute of Child Health, London, in the Behavioural Sciences Unit.

Training is usually carried out in 3 stages:

1. Training in the administration of the SOMA which includes background information on the development of the Schedule and practical experience. Trainees are then required to carry out a number of SOMA procedures and return their video tapes so that standardised presentation can be checked by the trainers. This section of the training usually takes approximately 4-5 days.

2. Training in the scoring procedures is the most intensive aspect of the training and takes 7-10 days depending on the participant's prior experience. Participants are expected to provide tapes that can be used in the training which may be relevant to their particular client group.

3. The final training module consists of reliability training and involves each participant rating a set of training tapes so that inter-rater reliability can be established. If the participant achieved the desired standard of reliability then she/he is credited as having completed the training course.

Administration Procedures

General

There must be at least 4 teaspoons or 4 bites of each foodstuff. There must be at least 3oz of liquid in each container (bottle and cups).

Each food type is presented to the child in 3 separate trials.

The child's mouth must be completely emptied before another trial is presented.

The examiner attempts, where possible, to administer the assessment in the stated order for ease of scoring. However, it is accepted that with particular children this is not always possible.

Each trial should be presented without undue rush to give the child time to respond with anticipatory movements, etc.

At the end of each set of trials the child is given the opportunity to display adaptive skills such as finger feeding, spoon feeding, etc., to estimate the level of independence in self-feeding development.

A list of references is detailed below:

Mathisen, B. et al. (1989) Oral-motor dysfunction and failure to thrive amongst inner-city children. *Developmental Medicine & Child Neurology*, **31**, 293-302.

Reilly, S. and Skuse, D. (1992) Characteristics and management of feeding problems in young children with cerebral palsy. *Developmental Medicine & Child Neurology*, **34**, 379-88.

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Skuse, D. et al. (1992) Failure to thrive. Clinical and developmental aspects. In: Remschmidt, H. and Schmidt, M. (eds) *Child and Youth Psychiatry. European perspectives. Vol II: Developmental Psychopathology*. Hogrefe and Huber: Gottingen.

Foodtypes:

Purée

1 pot Chambourcy chocolate mousse
1 pot Fromage Frais
1 jar Heinz/Boots pure fruit *(alternative if child is allergic to dairy products)*

Semi-solid

1 tub Tesco plain cottage cheese
1 tin Tesco petit pois

Solid

1 tub Mattison's potato salad
1 tin Waitrose fruit cocktail in pure fruit juice

Biscuits

a) Tesco crispbread
b) Tesco poppy/sesame crackers
c) Tesco oatcakes

Dried fruit (1 pack)

- apple/apricot/pear

Liquid

1 flask ≈9oz pure apple juice

Equipment:

Clear plastic teaspoons with flat bowl - Cannon Babysafe
Baby bottle - 4oz with standard teat - Cannon Babysafe
1 clear trainer cup - double handled - Cannon Babysafe
1 lipped clear cup
1 NUK pre-toothbrush kit
1 plastic Bendi straw
4 clear food containers
Disposable bibs

Appendix 4

FAS

Feeding Assessment Schedule

Manual

Sheena Reilly
David Skuse
Berenice Mathisen

Add in Acceptance page

FEEDING ASSESSMENT SCHEDULE

Methods of scoring:

Each trial is scored in one of four ways:

- Accepted - where the infant's mouth opens or is open to enable the spoon food or spout, etc., to be delivered within 30 seconds of presentation.

- Refused - the infant clearly indicates her/his unwillingness to accept the food or drink being offered. These refusals may be expressed in a number of different ways, which are fully explained in the refusals section.

- Omitted - an omitted trial is one in which the examiner did not administer or cannot be found on the video.

- Not ratable - trials that cannot be scored because of -

1. poor video quality - eg, out of focus.
2. interference eg, other sibling causing chaos.
3. hand in view, that is where the examiner's hand obscures the camera and the items cannot be scored.
4. incorrect presentation, where the food on the spoon is scraped off onto the child's lips.
5. inadequate food presentation, where the child is presented with only one pea on the spoon, etc.
6. where the child immediately removes the food from his/her mouth and subsequent items cannot be scored.

Individual items are scored in one of three ways:

1 = present

0 = not present

No = not observed - this may occur when the child chews/munches etc., with his/her mouth closed and therefore tongue movements cannot be seen and are therefore rated as not observed.

Categories

There are 15 food categories to score and 14 liquid categories. Each category and its individual items are scored as is described in the scoring codes.

The categories include:

Food types	No. of items
Body positioning	13
Head positioning	4 and 4
Refusal behaviours	9
Adaptive skills	14 (variable)
Reactivity	5
Acceptance behaviours	2
Food loss	3
Drooling	4
Sequencing/Rhythmicity	4
Initiation	3
Lips	13
Tongue	18
Jaw	21
Swallowing	12
Oral transit time	1

BODY POSITIONING

Body positioning is scored during the administration of the FAS. Facilities depend entirely on the family's resources, ie, if there is a highchair present, etc.

It is also highly dependent on the infant's cooperation to be seated in the desired chair.

The examiner always elects for the optimum seating position in which to provide the infant with the most appropriate and adequate seating support.

BODY POSITIONING

SUPINE	The infant is positioned on its back.
PRONE	The infant is positioned on its front.
SUPINE/PRONE WITH ELEVATED HEAD	The infant is in either of the above two positions with the head raised. This may be with the support of an adult or cushions, etc. Note type of support.
SIDE LYING	The infant is lying on either side - note if support given.
SEMI-SITTING WITH SUPPORT	The child is sitting in a semi-upright position with full trunk support. This may be provided by either an adult, a chair or by cushions.
SITTING UPRIGHT WITH TRUNK SUPPORT	The child is sitting in an upright position but with the trunk being supported by either cushions, a harness, padding, etc.
SITTING UPRIGHT WITH BACK SUPPORT	The infant is sitting in an upright position but with back support only. That is the child may be leaning back against the chair for support, etc. This may occur occasionally.
SITTING UPRIGHT WITHOUT SUPPORT	
WALKING AROUND	
SPECIAL SEATING	
OTHER	

HEAD POSITIONING

Head positioning - refers to position of child's head in relation to spoon and examiner.

FORWARD FLEXION	The head flops/bent forward onto the chest.
SIDE FLEXION	The head flops/bent sideways either to the right or to the left.
EXTENSION BACKWARDS	The head is extended backwards or flops backwards.
EXTENSION FORWARDS	The head is extended forwards away from the body with the chin pointing upwards.

DEGREE OF SUPPORT PROVIDED

NONE	
PARTIAL	Some degree of support is requested but not more than 12% of the time during the trial. This help may be from an adult steadying the child's head or from aids such as chair pads, cushions, etc.
MODERATE	As above but may occur up to 50% of the time.
TOTAL SUPPORT	The head requires constant support and positioning throughout the trial.

TONGUE (sucking)

ELEVATION/DEPRESSION

EXTENSION/RETRACTION

TONGUE TIP ELEVATION

CUPPING/THINNING (see definitions as for food types)

THICK BUNCHED TONGUE

TRANSIENT/MINIMAL TONGUE PROTRUSION

CONSISTENT-CONSIDERABLE TONGUE PROTRUSION

TONGUE PROTRUSION BETWEEN THE INCISORS

TONGUE PROTRUSION BEYOND THE LOWER LIP

TONGUE THRUSTING

ASYMMETRY

REFUSALS

WHAT TO DO WHEN A CHILD REFUSES ALL THREE TRIALS

On the FAS scoresheet there are four trials to be scored. Trial four is a self feeding trial (see notes re: self feeding trial). On some occasions with very difficult children all three trials and sometimes more are refused. The child may then suddenly accept a trial.

Scoring

The first three trials are scored refused as is required on the FAS and the refusals coded. However, this leaves the examiner with no information about the child's oromotor skills which is one of the major reasons for administering the assessment.

Separate sheets (FAS) have been provided to enable the examiner to at least record some information about the child's oromotor skills.

The sheet is headed with the trial number being scored eg, trial no 9 and this trial is then scored in the normal way. (see attached sheet for examples).

REFUSALS

Refusals: clear indications of the infant's unwillingness to accept the stimulus being offered. These may be expressed in a variety of ways.

Mouth closure	Firm approximation of the lips or jaw which does not allow the food or drink, etc., to be inserted in the mouth.
Head aversion	Turning away from the stimulus in an effort to avoid contact or acceptance. The head may be turned in any direction or extended in any manner.
Hand defence	The hands are raised/shaken/moved to cover the mouth or face, etc., to prevent the spoon, etc., approaching the mouth.
Walks away	The infant moves away or tries to escape from the situation by crawling, etc.
Throws food and equipment	Food, drink or any items of equipment are thrown or pushed away or off the tray or table.
Aggression to the examiner	In response to the presentation of food or equipment the infant hits, slaps, pinches or displays any other form of aggression to the examiner.
Facial grimaces	Any facial expression which displays dislike or disgust or any negative emotion about the proceedings.
Body withdrawal	Physical withdrawal away from the stimulus. The infant pulls back or moves his body away, without actually walking away, from the food or the drink.
Vocalises 'No'	The infant shakes his/her head to indicate 'No' or says 'No' in response to the food being offered.
Passive refusal	Child ignores food/drink entirely. Makes no movement/actions to participate.
Wastebasket	Child may put food/drink, eg, straw to mouth, but no attempt to do anything - may bite on straw/plays with it only.

ADAPTIVE SKILLS

Self feeding Trial no 4

Unfortunately there will not be adaptive skill information on all the children in the study. The children seen by BM and some of SR's early children were not administered this part of the FAS. Therefore, these trials (no. 4) should be scored as omitted on the scoresheets.

However, there are some scoring difficulties which will require sorting out:

1. The categories:

biscuits, soft, medium and hard
dried fruit
bottle
trainer cup
cup

should all be self-feeding trials and there is really no need to have a fourth trial in these categories. This trial has remained for ease of designing the scoresheets.

2. In case of

a) A difficult child who won't feed itself;

b) A controlling mother who won't allow the child to feed itself; it should be made clear that although the mothers are instructed not to over control, etc., this is often difficult to enforce especially if a mother's help is needed to gain the child's cooperation.

In the case of the difficult child who will not feed itself and the only alternative is to feed him/her the examiner omits this about the child's oromotor skills.

The procedure is the same for the over controlling mother who won't allow her child any freedom.

c) In some cases adaptive skills are not specifically tested yet there is some information about the child's self feeding skills as the child does insist on feeding itself part of the time. However, there is not full information on the child. In this situation there are two alternatives:

1. What information is available can be scored and the rest omitted. Or,

2. The whole trial should be omitted.

ADAPTIVE SKILLS

FIST TO MOUTH	
THUMB TO MOUTH	
OBJECTS TO MOUTH	
HOLDS SPOON	The infant is able to hold the spoon appropriately by the handle and not by the bowl. The spoon may be upside down or held sideways.
SCOOP FEEDING	The infant scoops the food up in the palm of the hand and is able to transfer it to the mouth.
FINGER FEEDS	The infant is successfully able to feed crackers, small pieces of food, etc., in any manner apart from scoop feeding or pincer grasp feeding.
HOLDS BOTTLE	The infant is able to hold the bottle only.
USES TRAINER CUP	The infant is able to hold the trainer cup and align with the mouth but is not able to tilt it sufficiently for drinking.
PINCER GRASP FINGER FEEDING	The infant is able to finger feed pieces of food using a thumb and forefinger grasp.
SPOON TO MOUTH	The infant is able to bring the loaded spoon to his mouth and align it correctly. The spoon is correctly gripped by the handle.
USES LIPPED CUP WITH HELP	The infant is able to pick up the cup and align with his mouth but needs considerable help to prevent spillages and steady the cup. He may not be able to tilt the cup.
SPOON FEEDS SELF	The infant is able to load the spoon with the minimum of help and transfer it to the mouth with the minimum of spillages. For example the child may load the spoon but spill one or two items such as peas from a loaded spoon.
USES LIPPED CUP INDEPENDENTLY	The infant is able to drink independently from a lipped cup and needs no help in steadying it, bringing it to his/her mouth or controlling the liquid.
DRINKS FROM TRAINER CUP	The infant can pick up and bring the trainer cup to its mouth and can tilt the cup and drink from it successfully.
DRINKS FROM LIPPED CUP WITH HELP	The infant is able to drink from the cup but needs some help in either steadying the cup, lifting the cup or helping to control the liquid flow.
DRINKS FROM THE BOTTLE	The infant is able to pick up, align the bottle and drink from it with no help.

REACTIVITY

HEAD ORIENTATION TO FOOD	The infant moves his/her head, body or trunk towards the spoon or drink. This movement may involve trunk or head extension or a variety of other movements. This movement should be carefully checked in slow motion on the video.
ANTICIPATORY MOUTH OPENING	As a result of the spoon, food or drink approaching the infant's mouth opens in order to accept the food. In order to score present the child must fully open both the lips and the mandible. However, different degrees of 'wideness' are acceptable.
INCREASED TENSION	As a reaction to the food, etc., approaching there is a noticeable increase in body tension. Either the head or neck or both may tense. The whole body may show changes in tension or it may be restricted to one part.
FOOD REMOVAL	Although the examiner has been able to present the food to the child the child immediately removes it or expels it.
NO FOOD ENTERS THE MOUTH	The food is presented to the child but may not be kept in the mouth because: 1. The child is not able to bite a piece of biscuit, etc., off and therefore there is no chewing, etc. 2. The loaded spoon is presented and placed in the child's mouth but no food remains there because of poor lip actions or poor presentation by the examiner or the child has its mouth habitually open. 3. The child wants the food/drink but perhaps because of poor adaptive skills he/she cannot for example tip the cup/bottle up to obtain the drink.

FOOD LOSS

(Based on Morris' estimates of 12 month competence)

NONE/TRIVIAL	Once food has been inserted in the child's mouth the amount of food lost is less than 10% of the total inserted.
MODERATE	Once food has been inserted in the child's mouth the amount of food lost is 10-30% of the total.
PROFUSE/MARKED	Once food has been inserted in the child's mouth the amount of food lost is considerable and more than 30% of the total.

DROOLING

NONE/TRIVIAL	The frequency with which the child is noted to drool within a trial is less than 10%.
MODERATE	The frequency with which a child is noted to drool is less than 25%.
PROFUSE/MARKED	The frequency of drooling is more than 25%.
ASSYMETRICAL	Any escape of liquid/food that is noted to be asymmetrical, ie, liquid escaping from one corner of the lips only.

SEQUENCING/RHYTHMICITY

SMOOTH SEQUENCE	A smooth sequence of at least 3 or more suck swallows, munching actions or chewing actions are seen. There are no coordination difficulties with integrating suck swallow or chew/munch-swallow, etc.
ARRYTHMIA	Noticeable incoordination of the sequence, either suck swallow, munch/chew-swallow, etc. The child may not be able to sequence these actions or there may be pauses in between, short jerky bursts of movement, etc. During drinking, for example, straw drinking, there may be a loss of pressure and an inability to sustain the pressure necessary to continue sucking.
PANIC REACTIONS ON ATTEMPTS TO SEQUENCE	The child visibly panics when attempting to sequence any of the mentioned actions. This may be evident in eye widening, an increase of tension or occasionally by gagging.
CHOKING	Any choking episodes that occur throughout the trial.

INITIATION

INITIATION	Time taken for the sequence to be initiated in seconds. Timed from when the food/drink/spout, etc., is placed in the child's mouth and the spoon is withdrawn until the first recognisable suck/chew/munch is observed.
NO. OF ATTEMPTS	That is the number of attempts the child makes at initiating the sequence. For example, the child may try to initiate sucking a number of times or he may attempt to bite the biscuit a number of times before being successful.

LIPS

LOWER LIPS DRAWS INWARDS AS SPOON IS REMOVED	Morris describes this as part of the process of separation of movement-the development of skill and precision, that is, the lips no longer move in unison with the jaw or tongue and the lower lip can mould around the spoon and draw inwards to help keep food in the mouth when the spoon is withdrawn.
UPPER LIP ACTIVELY REMOVES FOOD FROM THE SPOON	The upper lip is able to move forwards and downwards to help clean the spoon of food or remove food from the spoon. The lips may mould completely around the spoon or the midpoint of the upper lip may make contact only. As with point 1 part o the separation of movement.
LOWER LIP POSITIONED BEHIND UPPER INCISORS TO CLEAN AND RETRIEVE	The lower lip is moved against the upper teeth or gums or lips in order to clean and retrieve small pieces of food.
LOWER LIP POSITIONED BEHIND UPPER INCISORS/GUMS AS PART OF TOTAL SUCKING PATTERN	The child's sucking pattern includes drawing in the lower lip in a retracted position as the child sucks. Morris would describe this possibly as lack of separation of movement. The lips do not move independently.
LIP RETRACTION	The lips are retracted tightly to reveal the teeth or gums. The lips play no functional part in feeding as they are tightly retracted, this may be part of a total pattern of extension, etc.
PURSE STRING RETRACTION	The lips are very tightly pursed forward rather than in a fully retracted position. The are partially open and rounded and the gums or teeth may not be visible as in the above.
LIPS CLOSE AROUND STIMULUS DURING BITING	Both the upper and lower lips close and mould firmly around the biscuit during biting.
LIPS CLOSED DURING MUNCHING/CHEWING/SUCKING	The lips are closed during any of the above actions.
THE LIPS ARE CLOSED INTERMITTENTLY DURING MUNCHING/CHEWING AND SUCKING	The lips are closed for part of the sequence of chewing and munching (about 50%). It would not be normal for the lips to be partially or fully open during sucking but during munching or chewing this would be acceptable.
UPPER LIP ACTIVE DURING CHEWING AND MUNCHING	The upper lip is active during any of the above sequences. Initially this movement is not separated from the total movement patterns of the jaw and tongue, however, this separation takes place and the upper lip can function independently. This movement may be to help in the cleaning process such as moving down in order to clean with the lower lip.

LOWER LIP ACTIVE DURING CHEWING/MUNCHING	As above the lower lip can function independently of other organs.
LIP ANGLES, CHEEKS, ACTIVE DURING CHEWING, SUCKING AND MUNCHING	As above. The lip angles in particular may help to keep particles in the mouth and are often seen working when the infant is chewing a large lump. There is often tightening of the corners of the mouth and the cheeks may help to keep food positioned.
LIPS CLOSED DURING SWALLOW	

TONGUE

BITING

SUCKS ON FOOD AS ONLY RESPONSE	The infant makes no attempt to bite the biscuit/fruit and sucks on the food.
TONGUE PASSIVE AND RESTS UNDER THE FOOD	The tongue rests passively under the food and in no way interferes with the biting actions. It may retract slightly as biting takes place.
TONGUE THRUST INTERFERES WITH BITING	The tongue thrusts/protrudes forwards and makes biting difficult/impossible. The teeth are not able to align on the biscuit and therefore biting cannot take place.
TONGUE MOVES FORWARD AND ANTICIPATES THE BISCUIT	The tongue moves in an anterior direction and 'feels' the position of the biscuit.

SUCKING/CHEWING/MUNCHING

EXTENSION-RETRACTION	Seen in early suckle and suck patterns, smooth and rhythmical actions as the tongue extends and retracts by moving in a posterior and then an anterior direction.
ELEVATION-DEPRESSION	Up/down suck pattern of the blade of the tongue against the palate or alveolar ridge - no elevation of the tip yet although it may sometimes occur in unison with jaw opening and closing. Elevation and depression of the midblade of the tongue.
TONGUE TIP ELEVATION	Indicates separation of movement. The tongue tip no longer moves in harmony with the jaw and can move and elevate independently.
CUPPING AND THINNING	This is a change in the internal configuration of the tongue to flatten and thin and cup around the stimulus. The amount of cupping reduces with age but the flattening and thinning does not (Morris and Sheppard). They mean, I think, as the infant becomes more apt at creating internal negative pressure there is less need for the extent of tongue cupping. In addition, the tongue is able to move and act more independently and control a variety of textures.
THICK BUNCHED TONGUE	In contrast to the above the tongue is in a thickly bunched shape in either a protruded or retracted position. This makes food presentation very difficult as the spoon cannot be placed in the mouth correctly.
GROSS TILTING	This is not yet a true lateral movement but rather a gross action of the body of the tongue to tilt or tip food towards the molars. The tongue tip is not usually involved.

LATERAL MOVEMENTS

CENTRE TO SIDE	Food is transferred from the centre of the tongue to the molar regions.
SIDE TO CENTRE	Food is transferred from the side or the molar region to the centre of the tongue.
SIDE TO SIDE	Food is transferred across the midline from side to side.
TRANSIENT/MINIMAL TONGUE PROTRUSION	See general definition re: tongue protrusion versus tongue thrust. The tongue protrudes on few occasions or as little as once when the cup is removed or upon swallowing.
CONSISTENT/CONSIDERABLE PROTRUSION	Where the tongue protrudes consistently throughout the sequence (more than 50% of the time) and represents a more infantile pattern of extension/retraction.
TONGUE PROTRUSION BETWEEN THE INCISORS	The tongue protrudes between the incisors but not beyond the lower lip.
TONGUE PROTRUDES BEYOND THE LOWER LIP	The tongue protrudes beyond the lower lip and may protrude under the cup or into the cup.
TONGUE THRUSTING	Is a consistent and regular pattern of tongue protrusion it may occur at rest as well as during feeding. It definitely interferes with spoon/food placement and the tongue protrudes below the cup or into the cup.
ASSYMETRY	Any asymmetrical positioning or movements of the tongue.

JAWS

SPOON FEEDING

GRADED JAW OPENING TO ACCEPT SPOON	Jaws are opened sufficiently to accept various amounts of food on the spoon. There is neither too wide or too narrow an excursion.

BITING

PHASIC BITE	Rhythmical bite/release pattern. There is a series of jaw openings and closings. This may occur from birth until 3-5 months when the gums or teeth are stimulated. Biting is not always or is minimally successful.
CONTROLLED SUSTAINED BITE	Functional well controlled bite on variations in materials, that is hard or soft biscuits. The strength of the bite is adequate to break pieces off. Strength is adjusted to suit hardness of the biscuit.
ASSOCIATED HEAD EXTENSION/MOVEMENTS	May be seen when biting any sort of biscuit. There is increased head extension or increased body and neck tension. May indicate a lack of strength or inadequate jaw stabilisation. (May be facial grimaces or increase in tension in the facial muscles).
TONIC BITE	Strong and sudden closure of the jaw when the teeth and gums are stimulated. Often may be difficult for the child to release the bite pressure or there may be a contrasting open mouth posture such as in jaw thrusting, after the bite has been released.
GRADED JAW OPENING TO ACCEPT VARIABLE THICKNESSES	The infant is able to grade different sized openings of the jaw to accept a variety of thicknesses or biscuit, etc.
BISCUIT BROKEN OFF AGAINST THE TEETH OR GUMS	The infant breaks off the biscuit against the teeth or gums rather than biting it. There may be insufficient jaw strength to break the piece off.
INSUFFICIENT STRENGTH TO BITE A PIECE OFF	Regardless of type/manner of biting the infant is unable to produce sufficient strength to enable him/her to break a piece off.
SUCKS ON BISCUIT	The child makes no attempt to bite on the biscuit or may make one or two feeble weak attempts and then sucks on biscuit as only response.
MOUTHS ON BISCUIT	The child makes no attempt to bite or suck on the biscuit, the only actions being of the mouthing kind. For example, the child may lick the biscuit or touch it with his lips, etc.

JAW STABILISATION

NOT REQUIRED OR MINIMAL	The child can separate lip and tongue movements from the mandible which now moves independently and there is no longer any need to bite down on the spoon to stabilise the jaw. There is little liquid loss during drinking or food loss during eating as the lips and tongue now exhibit a higher degree of control. There are much reduced vertical mandibular movements. (INTERNAL)
REQUIRED AND CONSIDERABLE	The child cannot separate these movements and needs to bite on the spoon or cup to stabilise the jaw. The jaw excursions are often wide and the lips and tongue move in unison with the mandible. Liquid loss may be great.
STABILISATION NOT FULLY ESTABLISHED	Jaw stabilisation exists for only part of the time, eg, 50% of the time and is not fully established.

GENERAL JAW

JAW THRUSTING	A strong downward extension of the mandible. Can occur during food presentation and during chewing. The jaw appears to be 'stuck' in an open position followed by a rapid closure.
JAW CLENCHING	Opposite of above. This is the rapid closure part of the action and makes opening of the mouth very difficult. Often associated with qa tonic bite or strong flexor/extensor pattern.
ASSOCIATED HEAD MOVEMENTS TO TRANSFER FOOD	The child moves his head sideways, that is, uses gravity to help tip the food from one side of the mouth to the other.
USES FINGERS TO TRANSFER FOOD	The child uses fingers to transfer the food from side to side or to transfer it back onto tongue, etc.

SWALLOWING

JAW ALIGNMENT/CLOSURE DURING SWALLOW	During the swallow the child aligns/closes his/her jaws thus providing a stabilised base on which to move the tongue for swallowing. This is regardless of lip closure or manner of swallowing. The child who does not align/close the jaw for swallowing often uses gravity, that is s/he tilts his/her head back to swallow or makes numerous attempts to swallow.
LIPS CLOSED DURING SWALLOW	As above with the lips firmly closed or approximated during the swallow.
INCREASE IN TENSION DURING SWALLOW	There is a noticeable increase in tension during the swallow or when preparing to swallow or while initiating a swallow. There may be clavicular elevation, neck tension and a general increase in body tension.
PANIC REACTION	The child visibly panics during any of the stages of swallow. This is sometimes best recognised during swallowing of whole lumps or when there is an unexpected rush of liquid. The child's eyes may widen in surprise and there may be a lot of associated body movements.
NO SWALLOW IS OBSERVED	This item is scored if the examiner cannot actually observe a swallow and there were no on the spot comments made.
USES GRAVITY/HEAD EXTENSION	The child uses gravity by tilting back the head to initiate the swallow pattern. There may also be other compensatory movements such as side tilting or head rocking.
NUMEROUS ATTEMPTS TO SWALLOW	The child has difficult in initiating a swallow and may be seen to make numerous attempts to actually begin swallowing. This may be recognised by gulping type efforts or chewing like movements of the mandible.
NASAL REGURGITATION	Any regurgitation through the nose of fluid or food indicating the likelihood of poor nasopharyngeal closure/palatal dysfunction.
GAGGING	Any gagging, heaving responses seen in response to food presentation. These may occur at the sight of food or the spoon or when food enters the mouth or when food is moved back on the tongue in preparation for swallowing.
VOMITING	Any vomiting that is seen either as an immediate or delayed reponse to feeding.
CHOKING	
ORAL TRANSIT TIME	Time in seconds ..... This is measured from the time the food is placed in the child's mouth until the examiner records a swallow. May be difficult to time on video.

LIQUIDS

BODY POSITIONING	As for food types.
HEAD POSITIONING	As for food types.
REFUSAL BEHAVIOURS	As for food types.
ADAPTIVE SKILLS	As for food types.
REACTIVITY	As for food types.
ACCEPTANCE BEHAVIOURS	As for food types.
SEQUENCING/RHYTHMICITY	As for food types.
INITIATION	As for food types.

FOOD LOSS/DROOLING

These cannot be separated as in foods and are therefore measured together. The measure is of both liquid and saliva loss during drinking which may be due to immaturity, lack of control, poor lip seal, lack of experience, etc.

NONE/TRIVIAL	Where the amount of liquid lost while drinking or through drooling is trivial and hardly noticeable. There is probably no leakage during drinking itself but perhaps a small amount at the end on the final swallow (<10%).
MODERATE	The frequency with which the child drools/loses liquid is less than 25%.
PROFUSE/MARKED	The frequency with which the child drools is greater than 25%. (Based on Morris' predictions of 12 month old competence).
ASYMMETRY	Drooling/liquid loss occurs in an asymmetrical pattern. That is the liquid escapes from one corner of the mouth only, etc.

TONGUE (sucking)

ELEVATION/DEPRESSION

EXTENSION/RETRACTION

TONGUE TIP ELEVATION

CUPPING/THINNING (see definitions as for food types)

THICK BUNCHED TONGUE

TRANSIENT/MINIMAL TONGUE PROTRUSION

CONSISTENT-CONSIDERABLE TONGUE PROTRUSION

TONGUE PROTRUSION BETWEEN THE INCISORS

TONGUE PROTRUSION BEYOND THE LOWER LIP

TONGUE THRUSTING

ASYMMETRY

LIPS

MARKED LIP RETRACTION	As for food.
PURSE STRING RETRACTION	As for food.
FIRM CONTACT AROUND NIPPLE/SPOUT	Upper lip and lower lip: both the upper and lower lip are firmly moulded around the teat/spout/straw/rim of the cup, etc. There is no leakage and the lip pressure on the surfce is such that the teat cannot be easily moved in the mouth.
INTERMITTENT-INCOMPLETE LIP CLOSURE	The upper and lower lip closure around the spout, etc., is not complete and may be either weak or inconsistent closure. The seal is weak and there may be intermittent liquid loss.
LIPS CLOSED DURING SWALLOWING	As for food.
LIPS OPEN DURING SWALLOWING	As for food.

SWALLOWING

ALIGNMENT/CLOSURE DURING SWALLOW	The jaws are closely aligned during the swallow although the lips may not be. Jaw closue enables jaw stabilisation to develop and provides the tongue with a stable base by which it can initiate movement.
LIPS CLOSED DURING SWALLOW	The lips are closed firmly during the swallow. There is no escape of liquid.
INCREASE IN TENSION	As the child swallows there is an increase in tension which may be identified by clavicular tension, shoulder raising, facial tension, increased effort as indicated by closing the eyes and gulping when swallowing as if the child has swallowed a large pill.
PANIC REACTION	Similar to above. The child may indicate panic in differing ways such as eye widening, coughing/choking, body withdrawal, hand raiding, etc.
NO SWALLOW IS OBSERVED	This may occur frequently when video rating as it is often difficult to accurately assess and most importantly observe the swallow in this way. In a number of children it is impossible to tell if they actually have swallowed or not.
USES GRAVITY/HEAD EXTENSION	When swallowing the child uses gravity that is they tip the head backwards or perhaps sideways to either initiate or assist swallowing. It is hypothesised that they do this to trigger reflexive swallowing as they are not able to voluntarly control the preparatory or initial stage of swallowing. In addition, the child with tone problems may trigger off an extension pattern or increase flexor tone because of the increased effort required to initiate a swallow.
NUMEROUS ATTEMPTS TO INITIATE SWALLOW	When preparing to swallow the child may attempt to do so a number of times in an effort to prepare the food for swallowing or in an effort to trigger the swallow.
NASAL REGURGITATION	
GAGGING	
VOMITING	
SUCK SIP SWALLOW SEQUENCE STOPPED VOLUNTARILY	As the child is sucking s/he is able to stop the sequence with the straw, etc., still in her/his mouth. If the child is unable to do this s/he will pull the straw away or his/her mouth away in an effort to stop sucking.
CAN MOVE LIQUID IN STRAW BUT NOT FULLY SUCK UP	The child is able to create enough negative pressure to suck the liquid some way up the straw but is unable to get the liquid to its mouth.
CHOKING	

ORAL TRANSIT TIME (see previous notes under solids)

JAW SUCKING

SMALL VERTICAL JAW MOVEMENTS

WIDE VERTICAL JAW MOVEMENTS

JAW THRUSTING

JAW CLENCHING

REPETITIVE BITING - PHASIC BITE

JAW ALIGNMENT DURING SWALLOW

WIDE JAW EXCURSIONS

SMALL JAW EXCURSIONS

COMBINATIONS OF WIDE AND SMALL JAW EXCURSIONS

EXTERNAL JAW STABILISATION

-required 100%

-not required

-required 50%